From:	Singerman, Joel
To:	Morgan, Melinda; Region2 SFRecordCtr; Keating, Robert
Subject:	Wolff-Alport AR
Date:	Friday, December 23, 2016 8:33:17 AM
Attachments:	RI Excerpt 5-7.pdf

Please add this email and attachment to the AR for Wolff-Alport (a ROD is planned for this fiscal year).

From: Charp, Paul (ATSDR/DCHI/EB) [mailto:pac4@cdc.gov]
Sent: Monday, December 19, 2016 10:41 AM
To: Singerman, Joel <Singerman.Joel@epa.gov>; Graziano, Leah T. (ATSDR/DCHI/EB) <lge2@cdc.gov>
Cc: Trubiano, Anthony (ATSDR/DCHI/EB) <mto8@cdc.gov>; Parham, Alan (ATSDR/DCHI/OD) <axp9@cdc.gov>
Subject: Wolff-Alport RI

Mr. Singerman,

We have reviewed the Remedial Investigation (RI) for the Former Wolff-Alport Chemical Company and offer the attached comments.

ATSDR reviewed the specific chapters in the RI that would pertain to the interests of the Agency for Toxic Substances and Disease Registry (ATSDR) and the protection of public health. Specifically, we reviewed chapters 5, 6, and 7.

Our comments are included in the attached file as added text or comments embedded in the pdf file.

Thanks,

Paul A. Charp, Ph.D.
Senior Health Physicist
Division of Community Health Investigations
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Section 4

Nature and Extent of Contamination

This section discusses the type and distribution of contamination at the site. Section 4.1 discusses the approach to the evaluation, with the use of applicable screening criteria to characterize site contamination. Sections 4.2 through 4.8 present the nature and extent of contamination in site media.

4.1 Approach to the Evaluation of Contamination

The characterization of site conditions emphasizes the spatial distribution of contaminants in site media. All detected contaminations were subject to a media-specific screening process and are presented on the tables and figures in this section. The following evaluation of the nature and extent of contamination focuses on radiological contamination present as Th-232 and Ra-226. Although all detected contaminants were subject to the media-specific screening process, they are not all discussed to the same level of detail in the following sections.

Data used for this evaluation includes data collected in previous investigations discussed in Section 1.2.3.

4.1.1 Data Quality

Prior to evaluating the nature and extent of contamination, all analytical data were reviewed to evaluate the usability of the data collected and to determine whether the quality objectives and user requirements outlined in the WACC Site Final QAPP (CDM Smith 2015a) were met. The data quality assessment for the RI sampling is included as **Appendix J**; the field sampling, validation processes and achievement of the data quality objectives are discussed.

As noted in the data quality report, only the final qualified data are presented in the RI report. Data that did not meet quality control (QC) criteria were appropriately qualified during data validation as either estimated "J," "J+," "J-," and usable; usable but non-detect "U," "UJ," or as rejected "R" and not usable.

Section 5 in Appendix J summarizes the reasons some data were rejected during data validation of the RI sampling data. Appendix J-1, Tables 10 to 13 and the completeness tables in Section 5 show the percentages of analyte results that were rejected. The information in the completeness tables includes only environmental samples, whereas the summary below includes all samples (environmental and QC) collected during the RI sampling events.

Appendix J Tables 10 through 13 show the number of sample results qualified as estimated or rejected for the soil, sediment, groundwater, and concrete chemical and radiological data. For the soil samples, 125 results including metal, pesticide, VOC, and SVOC results were rejected. For the sediment samples, 36 radionuclide results were rejected. For groundwater samples, five pesticide results were rejected. For the concrete samples, five radionuclide results were rejected.

The data that were not rejected are considered definitive data collected under an EPA-approved QAPP. The analytical chemistry samples were validated by CDM Smith according to the National Functional Guidelines (NFGs) for Superfund Organic Methods Data Review (August 2014a); EPA NFGs for Inorganic Superfund Data Review (August 2014b); and EPA's Region II validation criteria and standard operating procedures (SOPs). The radiological data were validated by VALIDATA Chemical Services, Inc., Duluth, Georgia according to Greenwich Environmental Designs (GED) SOP 4.8; Data Validation Protocol for Field Data Collected using Canberra's In-Situ Gamma Spectrometer (June 2015); and the Multi-Agency Radiological Laboratory Analytical Protocols Manual (United States Nuclear Regulatory Commission 2004). Any actions taken in those instances for chemical data where the NFG relies on the professional judgement of the validator are noted in the individual data validation narratives.

All estimated data results may be used for their intended purpose to evaluate the nature and extent of contamination and evaluate risks. The final percentages of valid data for the RI sampling are 99 percent for groundwater, 99 percent for soil, 96 percent for sediment, and 91 percent for concrete. Valid data for all media exceeded the completeness goal of 90 percent. The rejected data should not be used for project decisions.

4.1.2 Use of Data

4.1.2.1 Principal Contaminants

The discussion in the sections below will focus on the presence of Th-232 and Ra-226 as these are considered the two principal radiological contaminants that have been identified by the CDM Smith RI as well as previous investigations conducted by the EPA and NYSDOH for the WACC site. In general, their decay chain progeny are expected to be at the same activity level as the parent. U-238, the decay chain parent of Ra-226, will also be present. For risk analysis and screening purposes, the U-238 concentrations are assumed to be that of the Ra-226 progeny. This is a conservative assumption in that the sulfuric acid used as the agent for solubilizing the monazite ores in the rare-earth extraction process would preferentially concentrate the Ra-226 in the waste sludge (Korkisch 1969).

4.1.2.2 Use of ISOCS Data

The Canberra In-Situ Gamma Spectroscopy system known as ISOCS was deployed in the field to provide quick turn-around analysis for the presence of the two principal contaminants (Th-232 and Ra-226) in soils and sewer sediments at the site. Because Th-232 is not detected by gamma spectroscopy, the decay progeny of Th-232, Ac-228, was used as a surrogate measure for Th-232. Using Ac-228 as a surrogate for Th-232 is a reasonable assumption because the Th-232 decay chain is in secular equilibrium within the site soils. To ensure the use of the ISOCS system would provide a reliable and accurate assessment of soil contaminants, a sub-set of duplicate samples were collected and sent to a certified radiochemistry laboratory for an independent gamma spectroscopy assessment.

The 41 samples sent offsite for gamma spectroscopy analysis covered a range of concentrations, with over 80 percent of the selections containing concentrations less than 5 pCi/g of combined Ra-226 and Th-232. The sample measurement comparison was biased in this range because decisions regarding the extent of contamination and exposure risks will be based on concentrations in the lower range of concentrations for combined Ra-226 and Th-232, as the

state if above background or if the 5 pCI/g includes background see 40 CFR 192 higher concentrations also found in soils at the Site are well above the screening criteria or any threshold that will likely indicate risk. Consequently, a high level of confidence that the ISOCS onsite laboratory provides reliable data was needed within the lower concentration range. The ISOCS data were compared with the laboratory results using a simple linear regression. As shown in **Figures 4-1** and **4-2**, the correlation coefficients for both Ra-226 and Th-232 were greater than 0.98. This correlation coefficient is statistically considered to be an excellent correlation, indicating that the ISOCS data is accurate with respect to the laboratory analysis data, and can be considered to provide Th-232 and Ra-226 results as reliable as the laboratory data.

4.1.3 Selection of Screening Criteria

4.1.3.1 Chemical

RI screening criteria were selected to evaluate chemical contaminants detected in study area media, as presented in **Tables 4-1 and 4-2**. The selected criteria were used to evaluate the nature and extent of contamination based on the RI analytical data. Whenever possible, established regulatory criteria, known as chemical-specific applicable or relevant and appropriate requirements (ARARs) were used for the screening criteria values. In the absence of ARARs, guidance values, known as “to be considered”, were used.

Soil Screening Criteria

The soil screening criterion for each chemical contaminant is the lowest of the EPA Regional Screening Levels (RSLs) for residential soils, NYSDEC Restricted Use Soil Cleanup Objectives, and NYSDEC Supplemental Soil Cleanup Objectives. Exceedances of the screening criteria are summarized in the remainder of Section 4. **Table 4-1** presents the RI soil screening criteria.

Groundwater Screening Criteria

The groundwater screening criterion for each chemical contaminant is the lowest of the Federal Maximum Contaminant Levels (MCLs), EPA RSLs for Tap Water (cancer risk = 1 x 10^{-6} [1 in 1 million]; noncancer hazard quotient = 0.1), and NYSDEC Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations. **Table 4-2** presents the RI groundwater screening criteria.

4.1.3.2 Radiological

The radiological screening criteria are presented in **Table 4-3**. Typically, screening criteria are developed based on a cancer risk of 1 x 10^{-6}. However, since radiological contaminants exist naturally within background soils, the cancer risk-based screening values would be less than the corresponding background soil concentrations.

Therefore, as specified in an EPA guidance directive for comparing background and chemical concentrations in soils for CERCLA sites (EPA 2002b), the screening criteria for contaminants with natural background concentrations were determined from the analytical results from background samples collected during the RI. In this specific instance, the upper tolerance levels (UTLs) for the background sample concentrations (soils, sediment, and air), as calculated using ProUCL (EPA 2015a), were used as the screening criteria for the naturally occurring radionuclides (Th-232, U-238, and their respective decay progeny) identified on and around the WACC site.

4.1.4 Development of Site-Specific Background Values

Background soil and sediment samples were collected to provide a baseline comparison for the naturally occurring radionuclides that are the radionuclides of concern at the WACC site (Th-232 and Ra-226 in the soils and uranium and thorium nuclides in the sediment). The background samples provide data to use as a screening tool for identifying areas that are likely to have been impacted from historical site operations.

4.1.4.1 Background Gamma Scans

Background gamma scans were conducted to allow comparison between surficial soil background gamma count rates and potentially-impacted soil gamma count rates. The background data were used to identify hot spots in the site areas and assist in selecting sampling locations to determine the nature and extent of WACC contaminants. Scanned surfaces included asphalt, concrete sidewalk, and grass/dirt. Results are presented in **Table 4-4**.

The average collimated reading for grass/dirt from 7 locations was 3,504 cpm while the uncollimated reading for grass/dirt in 1 location was 8,133 cpm. The collimated readings for asphalt and concrete (one sample of each) were 5,528 cpm and 2,540 cpm, respectively.

4.1.4.2 Background Soil Sampling - Non-Radiological

Twenty-four soil samples were collected offsite at 8 locations (**Figure 2-2** and **Table 4-5**) to establish general background concentrations for chemical contaminants in urban soils in the area of the site. These background data are used in **Section 4.3** to better understand which contaminants are related to the WACC processes. Background soil concentrations exceeding the site screening criteria were limited to polycyclic aromatic hydrocarbons (PAHs) and metals that are typical of urban fill.

The following four PAHs exceeded the RI screening criteria:

- Benzo(a)anthracene: Background sample concentrations ranged from 5.4 to 670 micrograms per kilogram (µg/kg), exceeding the RI screening criterion of 160 µg/kg, with a median of 190 µg/kg. The maximum concentration was found in the surface soil sample (0 to 1 foot bgs) at BKSB-05.

- Benzo(a)pyrene: Background sample concentrations ranged from 4.8 to 720 µg/kg, exceeding the RI screening criterion of 16 µg/kg, with a median of 185 µg/kg. The maximum concentration was found in the surface soil sample (0 to 1 foot bgs) at BKSB-05.

- Benzo(b)fluoranthene: Background sample concentrations ranged from 7 to 1,100 µg/kg, exceeding the RI screening criterion of 160 µg/kg, with a median of 225 µg/kg. The maximum concentration was found in the surface soil sample (0 to 1 foot bgs) at BKSB-05.

- Indeno(1,2,3-cd)pyrene: Background sample concentrations ranged from 3.1 to 310 µg/kg, exceeding the associated RI screening criterion of 160 µg/kg, with a median of 68 µg/kg. The maximum concentration was found in the surface soil sample (0 to 2 feet bgs) at BKSB-01.

The following inorganics exceeded the RI Screening Criteria:

- Arsenic: Background sample concentrations ranged from 1.2 to 6.5 milligrams per kilogram (mg/kg), exceeding the RI screening criterion of 0.68 mg/kg, with a median of 3 µg/kg. The maximum concentration was found in the surface soil sample (0 to 2 feet bgs) at BKSB-02.

- Barium: Background sample concentrations ranged from 14 to 880 mg/kg, exceeding the RI screening criterion of 350 mg/kg, with a median of 44 µg/kg. The maximum concentration was found in the surface soil sample (0 to 1 foot bgs) at BKSB-05.

- Iron: Background sample concentrations ranged from 6,000 to 43,000 mg/kg, exceeding the RI screening criterion of 2,000 mg/kg, with a median of 13,000 µg/kg. The maximum concentration was found in a deep soil sample (23 to 25 feet bgs) at BKSB-04.

4.1.4.3 Background Soil Sampling (Radiological)

For the eight background borings described above, 27 samples were collected for radiological analysis for Ra-226, Th-232, and U-238 (**Table 4-11**). Observations include the following:

- Th-232: Background sample concentrations ranged from 0.487 pCi/g to 1.132 pCi/g. The maximum concentration was found in a subsurface soil sample (28 to 30 feet bgs) at BKSB-06.

- Ra-226: Background sample concentrations ranged from 0.176 pCi/g to 0.919 pCi/g. The maximum concentration was found in a subsurface soil sample (8 to 10 feet bgs) at BKSB-06.

- U-238: U-238 was not detected in any samples.

this is strange. not to detect uranium in a soil sample is extremely rare unless the soils are mostly sand

ProUCL (EPA 2015a) was then used to establish UTL values for soil Th-232 and Ra-226 background data. The UTL is commonly used as a means of establishing screening values for radionuclides that occur as part of the natural background. Otherwise, use of EPA risk screening criteria would result in all background levels exceeding the corresponding soil concentration. **Appendix K** presents the UCL calculations.

these bkg about 10x higher than above ground samples and higher than the backgroun in the next paragraph

4.1.4.4 Background Sewer Investigation

The sewer investigation conducted by BVNA in 2013 (BVNA 2014) included four background locations and established a background dose rate between 9 and 12 µR/hr and background gamma counts from manholes at 43,000 cpm.

During the RI, four portions of sewer lines were investigated for background information including two lines on Wyckoff Avenue, one on Eldert Street, and one on Cooper Street. The Cooper Street line was used for background runs south along Cooper Street originating at C-11 (**Figure 2-4**). No connection was found between the Irving Avenue sewer line and manhole C-11. From C-11 to C-15, all gamma readings were less than 5,000 cpm. The maximum gamma reading recorded in the background sewer lines was 4,900 cpm, collected from W-5 to W-6 which is across Wyckoff Avenue from manhole W-1. **Table 4-6** presents the background data collected from the sewer lines.

also, the value listed, 43000 cpm does not reflect text in this section, perhaps, too many zeros?

Fifteen manhole locations were investigated as part of the RI for background information along the background sewer lines discussed above. The average surface gamma readings for brick were at 1,505 cpm, with a maximum of 2,387 cpm in manhole D-2 located on Decatur Street. The average surface gamma readings for concrete were at 1,506 cpm, with a maximum of 1,900 cpm in manhole C-14 located on Cooper Street, south of Irving Avenue. **Table 4-7** presents the background data collected from the manholes.

why not sample upstream from outfall?

4.1.4.5 Background Sediment Sampling - Coney Island Creek

Twenty-eight background sediment samples were collected from eight locations (**Figure 2-6**) in Coney Island Creek to provide a baseline for comparison to evaluate if sediments near the Newtown Creek outfall were impacted by WACC operations. **Table 4-8** presents the isotopic results of the background sediment sampling.

could creek be impacted by ocean systems?

The sediment background samples were not analyzed using the ISOCS system. These samples were sent directly to the independent radiochemistry laboratory for analysis. In addition to gamma spectroscopy analysis for Th-232 and Ra-226, a mass spectroscopy isotopic analysis was performed to determine the levels of thorium and uranium in the sediment. As with the soil samples, ProUCL was used to establish the UTLs for each radionuclide. **Appendix K** presents the UTL calculations.

4.1.4.6 Background Air and Gamma Exposure Rates

No background samples were collected by CDM Smith for radon, thoron, or direct gamma exposure rates. As a result, other survey data sets were used to generate screening values. In the case of indoor radon, a NYSDOH data base (NYSDOH 2016) was used to establish UTLs for a basement and a first-floor area. Because the data were not validated, professional judgment was used to remove outlier data that would tend to bias the UTL to a non-conservative (i.e., higher) screening value.

A perimeter survey study (Weston 2013) performed in 2013 was used to establish screening levels for thoron and direct gamma exposure rates. The thoron data set from the study was modified to remove data points that were within an impacted area such as those on the WACC property or on streets immediately adjacent to the site. The data correction ensured the screening levels established would be biased toward a lower or more conservative value. ProUCL was used to establish the UTL for outdoor thoron. Because no indoor thoron background measurements were made, the outdoor values were used as screening levels for indoor thoron. This assignment would bias the screening level to a conservative or lower level.

For direct gamma exposure rates, the screening level was established at the upper end of the background range of exposure rate levels measured in the 2013 survey. This value was selected because it was the upper background value established by the survey team and NYSDOH, who sponsored the study. Because of complex variance due to geometries and surrounding building/surface materials involved in exposure rate measurements, the use of a statistical UTL would create an overly conservative screening value with no commensurate benefit for identifying potentially impacted areas.

4.1.5 Data Presentation

4.1.5.1 Chemical Data

The chemical analytical results from the Wolff-Alport RI were entered into the site database for evaluation purposes. The data were exported to GIS for graphical analysis and presentation. The data presented on the figures in this section are in units consistent with the data tables (**Tables 4-9 through 4-10**) as follows:

- Organic data for soils are presented in µg/kg
- Inorganic data for soils are presented in mg/kg
- Organic and inorganic data for aqueous samples are presented in micrograms per liter (µg/L)

The full data tables highlight contaminants that exceed the screening criteria.

4.1.5.2 Radionuclide Data

Gamma scans were conducted for the interior and exterior of the WACC property buildings, exterior soils, sewer pipeline, and sewer manholes prior to sample collection. The gamma scan data were used to supplement the sample analytical data results.

Gamma exposure rates were also recorded at selected locations within the WACC property buildings, exterior soils, and the sewer manholes; gamma exposure rates are presented in microrem per hour (µR/hr).

units are wrong. rem is a unit of dose; R is the unit of exposure

The radionuclides of concern at the site are Th-232, U-238, and Ra-226. Thorium, uranium and their respective decay chain progeny were re-concentrated from the original ore values as part of the WACC monazite sand processing. Monazite sands contain at least 6 to 8 percent of thorium and 0.1 to 0.3 percent of uranium with a Th-232 to U-238 ratio in the range of 3 to 1 to 10 to 1 (World Nuclear Association 2014).

Ra-226 is produced in the decay series of U-238. The minimum detectable activity (MDA) using gamma spectroscopy for U-238 is high; gamma spectroscopy results were not able to be used as a first line indicator for U-238. Instead, Ra-226 in combination with Th-232 concentrations were used to determine the nature and extent of contamination associated with WACC. The radionuclide analytical results were entered into the site database for evaluation purposes. The data were exported to a GIS for graphical analysis and presentation. The data presented on the figures in this section are in units consistent with the data tables (**Tables 4-11 through 4-18**) as follows:

- Radionuclide data for building materials, soils, sediment are presented in pCi/g
- Radionuclide data for groundwater are presented in pCi/L

The data tables highlight radionuclides that exceed the screening criteria.

Need better explanation of why Ra-226 and Th-232 are used in combination to determine contamination especially since they are not in the same decay chain and secular equilibrium between U-238 and Ra-226 is not applicable and may be difficult to delineate from background. Unless additional information is given, this combination usage is not too clear.

4.2 Results of the Building Investigation

The investigation of the WACC property buildings included radiological surveys and sampling of the building materials to determine if any process or effluent radioactive material became embedded in the building materials. This included:

- Gamma surveys of all building surfaces (floors, walls, ceilings, and roof) to determine potentially radiologically contaminated areas
- Wipe sampling to determine if radiological contamination is in the form of removable dust
- Building material core samples to confirm if elevated gamma scan readings are due to contamination embedded in the building materials

Data presented in the sections below include the RI data and the historic surveys performed before and after radiation mitigation activities (including installation of lead shielding below portions of the WACC property buildings). The historic reports are provided in **Appendix A** and include surveys completed by LBA, EPA RST 2, and NYCDDC.

In addition a hazardous building materials survey was performed as part of the RI to determine the presence of hazardous materials such as ACM, LBP, mercury, and PCBs.

4.2.1 Gamma Surveys

LBA (2010) conducted an interior gamma scan of the WACC property buildings prior to installation of the lead shielding in 2012. The investigation found background (6-10 µR/hr) to moderate levels in the survey areas located over the former exterior staging yard (shown in **Figure 1-3**). In aerial photographs, the piles of monazite sands and/or waste tailings are somewhat visible in the yards. The gamma levels indicate the presence of residual monazite sands and/or tailings from the former activities. The survey also found relatively high gamma and subsurface radioactivity levels in the front half of Lot 46 and in Lots 44 and 42, where the WACC processing buildings stood.

The EPA RST 2 (Weston 2014) conducted interior gamma scans at the WACC buildings immediately prior to and after the installation of the shielding as part of the radiation mitigation activities. The survey results were presented as exposure rates above background (10 µR/hr). At contact with the floor, the highest exposure rates (greater than 20 times background) were measured at Lot 44 (Primo Auto Body), Lot 42 (Terra Nova), at the former rail spur, and on the Irving Avenue sidewalk in front of Lots 44 and 42. The maximum exposure rates per area prior to shielding ranged from 65 to 430 µR/hr. After shielding was installed, maximum exposure rates per area ranged from 28 to 90 µR/hr. The highest exposure rates (greater than 6 times background) were found at Primo 1, Terra Nova, and on the Irving Avenue sidewalk.

2015/2016 RI

During the RI, gamma surveys were conducted to identify locations with elevated gamma counts to target for building materials sampling. The floors, walls, ceilings, and roof were surveyed at the WACC buildings (including Lot 33, Lot 42, Lot 44, and Lot 46). Results are shown in **Figures 4-3a through 4-3f.** Floor areas in Lot 42 and Lot 44 (Primo Auto Body area and the front area of Terra Nova) were not surveyed due to the presence of the lead/concrete shielding installed as part of the IRM in 2014 to cover areas of known contamination. A background gamma value of 2,500 cpm was selected for initially screening the building materials based on the background survey of concrete sidewalks.

Interior floor gamma survey results showed gamma readings greater than at least two times background for a majority of the scanned floors. In Lot 33, a warehouse above former yard areas, gamma measurements were greater than 4 times background in the northern corner of Lot 33-1, with the highest readings (8 to 20 times background) adjacent to either the back wall that runs along the former rail spur area or the west wall adjacent to Lot 42. The southwestern corner of Lot 33-1 and the middle of Lot 33-4 found gamma readings with concentrations greater than eight times background. In Lot 46 , the deli basement, elevated gamma readings greater than 20 times background were found in the center and in the southeast corner of the basement.

Interior wall gamma survey results were similar to the floor gamma results. In Lot 33-1, levels were mostly between 2 and 10 times background. Sporadic readings greater than 10 times background were found in the bottom half of the western wall and the northern wall adjacent to the former rail spur area where elevated floor readings were observed. Readings between 5 and 10 times background were also found along the front wall of Lot 33-4. A hotspot of elevated gamma readings greater than 10 times background was observed on the eastern wall of Lot 46 (deli basement) in the southeastern corner adjacent to the WACC processing building (Lot 44).

Floor gamma readings were not collected at Lots 42 and 44 but wall gamma scans were conducted. In the Primo Auto Shop Lot 44, elevated readings were observed along the bottom half of the eastern wall ranging from 5 to 10 times background. At Primo Auto Shop Lot 42, readings greater than four times background were observed in the wall separating the front and rear of the building, and sporadically along the western and eastern walls. At Terra Nova in Lot 42, readings between two and four times background were found along the eastern wall and the front wall along Irving Avenue.

The ceiling gamma survey results showed little radioactivity in the ceiling materials. Gamma readings between 5 and 10 times background were found sporadically on the ceiling in the southeastern corner of Lot 44 with a maximum of 17,300 cpm. Gamma readings slightly greater than two times background were also observed in two square-meter plots in Lot 46, Lot 44, Lot 42 (Primo Auto Body), the front half of Lot 42 (Terra Nova), along the wall facing Irving Avenue in Lot 33, and in the northern corner of Lot 33.

Gamma readings were only collected from the roofs of Lot 44, Lot 42, and Lot 48 due to the questionable structural integrity of the other buildings' roofs. Gamma readings collected on the roof were only greater than 10 times background in 1 location in the southwestern corner of Lot 44 (Primo Auto Body), which is coincident with the elevated ceiling gamma reading discussed above. The majority of the other gamma readings were less than two times background.

The exterior wall survey results saw the highest gamma readings in the front exterior wall of the WACC buildings. Results for the western wall of Lot 46 showed gamma readings ranging from 4,000 to 8,000 cpm in the brick of Flat Fix and 2,500 to 3,500 cpm in the stucco of Jarabacoa Deli. The highest gamma readings on the rear wall of the WACC buildings were found in the concrete wall of Lot 42 (Terra Nova). Gamma readings on the entire rear wall ranged from 3,000 cpm to

12,000 cpm. The eastern exterior wall saw gamma readings ranging from 5,000 to 6,500 cpm. The front wall of the WACC buildings saw gamma readings ranging from 2,500 cpm to 15,000 cpm. The most elevated gamma readings were found on the exterior front walls of Lot 44 and Lot 42 as well as the lots comprising Lot 33.

338-348 and 350 Moffat Street Gamma Scans

A supplemental investigation was performed at the 338-348/350 Moffat Street properties by EPA in 2015. EPA RST 2 completed gamma scans in 12 condos at this property south of the WACC property (EPA 2015b). The highest exposure rate measured at the contact surface of the test location was 12 µR/hr which is slightly greater than the EPA RST 2's designated background of 10 µR/hr. The highest thoron concentrations were also detected in this unit located on the first floor in the shed area behind the building. The air sampling results are discussed in **Section 4.3.2**.

4.2.2 Radiological Building Materials Sampling

During the NYCDDC RSS, seven areas of building surfaces were measured for the presence of removable and fixed alpha contamination. Most of the smear samples were collected from building floors. The results showed only one smear sample with elevated alpha results at 106 alpha disintegrations per minute per square centimeter (dpm/cm^2); the smear was located in Primo Auto Body Lot 42 near a floor drain. Repeat sampling in the area did not detect elevated radioactivity.

2015/2016 RI

Locations to conduct additional alpha/beta measurements, smear sampling, and building material core sampling were selected based on the results of the gamma surveys conducted throughout the WACC buildings. The alpha/beta results were compared to the acceptance criteria for Th-232 from Nuclear Regulatory Commission's (NRC) Regulatory Guide 1.86 (1974) on decommissioning release limits, 1,000 dpm/cm^2, to determine what areas contained elevated alpha. Wipe samples were collected from each alpha/beta direct measurement location to determine removable contamination. The results are presented in **Table 4-19**.

Direct alpha/beta measurements were greater than 1,000 dpm/cm^2 at three locations. At Lot 46 (deli basement) along the eastern wall near the south corner, BRICK-03-LOT46 had an alpha measurement of 10,776 dpm/100 cm^2. Elevated alpha measurements were observed on BRICK-06-LOT44, located in Lot 44, Primo Auto Body at 27,365 dpm/cm^2. The third location was collected in Primo Auto warehouse, in Lot 42. This brick (BRICK-09-LOT42) was underneath concrete and had an alpha measurement of 2,363 dpm/cm^2. The overlying concrete had an alpha measurement of 724 dpm/cm^2. All wipe samples collected at these locations showed no removable contamination.

At each location selected for direct alpha/beta measurements, samples of the building materials were collected and sent to a subcontract laboratory for gamma spectroscopy analysis. The highest results for Th-232 were observed in brick and concrete materials collected from the former kiln-vat building area (Lot 42 and 44). BRICK-09-LOT42, BRICK-06-LOT44, and CONC-07-LOT 42 had concentrations of 152.7 pCi/g, 415.2 pCi/g, and 57.6 pCi/g, respectively. BRICK-06-LOT44 was collected from a short brick wall in front of an arch between the two Prime Auto body bays, through which material entered the kiln oven for processing. The other brick sample was collected in the Primo Auto main shop, which operated as a kiln/vat building when used by WACC.

A brick collected from the basement of the deli (Lot 46) from the southern corner along the east wall had a Th-232 concentration of 7.8 pCi/g. The high gamma reading observed in this location was likely due to contaminated soils on the other side of the basement wall.

4.2.2.1 Hazardous Building Materials Survey

The hazardous building materials survey found ACM, assumed ACM, LBP, assumed LBP components, and suspect hazardous materials throughout the WACC building structures. ACM tar was used in the construction of the buildings and found in wire insulation and electrical panels, roofing materials, window caulking, and interior construction materials. LBP was found in the Terra Nova, Primo Auto Body, Flat Fix, Jarabacoa Deli, and the second floor apartment, and the exterior of K&M Auto. Mercury was assumed to be present in all fluorescent light bulbs and wall thermostats throughout.

4.2.3 Conclusions of the Building Investigations

- Contamination remains in the building structures at the WACC property, primarily in the buildings that previously operated the kiln/vat in which monazite sands processing took place and the storage yard where sands were loaded into the kiln-vat (Lots 42 and 44), in the basement of the deli (Lot 46), and, to a lesser extent, in the warehouse on Lot 33 constructed above the former yard area. Contaminants are primarily embedded in the building structure with the highest concentration of 415.2 picocuries per gram (pCi/g) on a sample of brick from Lot 44.

- ACM, LBP, and suspect hazardous materials found in the WACC building structures were comparable to a building of its age.

4.3 Results of Previous Site Air Sampling

Previous investigations evaluated radon concentrations in the WACC property buildings and the exterior property and neighborhood.

typical outdoor Rn 222 is about 0.5 pCi/L. Need to indicate a nominal background for thoron. Again, need to justify why you are doing a combined screening criteria especially since the two radons are in different decay chains.

4.3.1 WACC Property

<u>WACC Building Interiors</u>

An investigation conducted in 2010 (LBA 2010) found an elevated thoron concentration of 12.7 pCi/L. The screening criteria for thoron/radon is 1.4 pCi/L. This investigation found low levels of radon and thoron at Primo Auto Body, likely due to the large amount of air infiltration in the poorly-sealed buildings.

The Weston investigation collected radon samples from nine different locations before and after lead shielding was installed. Before the shielding was installed, the highest radon levels were found in Lot 42, Terra Nova, at 4.6 pCi/L, Lot 42, Primo Auto Body, at 3.1 pCi/L, and Lot 44 at 4.3 pCi/L. After lead shielding was installed, the highest radon levels were found in Lot 46, Jarabacoa Deli, at 3.5 pCi/L and Lot 42, Primo Auto Body, at 3.2 pCi/L. After the radon mitigation system and concrete/lead shielding were installed, all radon levels dropped below 2.0 pCi/L for Lot 44 and Lot 42, Terra Nova.

Exterior Sampling

The Neighborhood Radiological Assessment (NRA) (Multiagency 2013) conducted thoron/radon sampling outside of the WACC buildings and in the neighborhood surrounding the WACC property on concrete sidewalks, tree-skirts, and exposed surfaces beneath sidewalks. Background sampling was conducted with thoron measurements generally collected about 0.5 mile from the WACC property. The maximum thoron concentration of 0.3 ± 0.3 pCi/L was collected from the corner of Irving Avenue and Cooper Street. The report cited the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 2006) for their data, indicating thoron concentration in uncontaminated or non-impacted areas vary by an order of magnitude from 0.02 pCi/L to 2.7 pCi/L.

The EPA action level is for Rn-222 not Rn-220 (thoron)

4.3.2 338-348 and 350 Moffat

A supplemental investigation was performed at the 338-348/350 Moffat Street properties by EPA in 2015. Twelve condo units at this property were investigated for indoor radon and thoron (EPA 2015b). Thoron was detected above the EPA site-specific action level at 4 pCi/L in two condo units. One test in one unit located in the living room on the first floor had an average thoron concentration of 3.6 pCi/L ± 2.7 pCi/L, on the middle of the south wall. Three tests in the other unit, located on the first floor in a shed area behind the building, had thoron concentrations exceeding the action level with average concentrations ranging from 6.5 pCi/L ± 1.1 pCi/L and 8.5 pCi/L ± 1.1 pCi/L. This is the same location where the maximum gamma readings were observed.

4.4 Results of Soil Investigation

The soils investigation included gamma scan surveys, soil boring downhole gamma scans, and soil sampling to delineate the impacted soils at the WACC property and the surrounding properties. Soil sampling was also conducted for non-radiological parameters to determine if the site had other contamination.

Data presented in the sections below include the RI data, the historic investigations performed before and after radiation mitigation activities, and investigations conducted on neighboring properties.

4.4.1 Non-Radiological Soil Contamination

Samples were collected in the NYCDDC Phase II by LBA and during this RI to determine the extent of non-radiological contamination at the site. In addition, results from investigations at adjacent properties are included below. The RI results are presented on **Tables 4-19** and **4-10**.

4.4.1.1 WACC Soil Borings (Non-Radiological)

Previous Investigations

The NYCDDC Phase II investigation included the advancement of 30 soil borings and collection and analysis of soil samples and groundwater screening samples. In the report, soil sample results were compared to NYSDEC Technical and Administrative Guidance Memorandum #4046 (TAGM) Residential Soil Cleanup Objectives (RSCOs). Acetone was the only compound that exceeded the screening criteria in one sample at a location near the western side of Lot 48. Low-level detections of acetone were reported in all other samples except one sample in which acetone was not detected. Low level detections of 2-butanone and methylene chloride were exported in samples collected throughout the site. Arsenic, beryllium, chromium, copper, iron, mercury, nickel, and zinc were all detected above TAGM RSCOs. Low-level detections of 4,4'-dichlorodiphenyldichloroethane (4,4'-DDD) and endrin ketone were reported in one soil sample collected from a sample across Cooper Street from the WACC property.

RI Sampling

Fifty-nine soil borings were advanced at the WACC property with surface and subsurface soil samples collected for TCL VOCs, SVOCs, PCBs, pesticides, and TAL metals at pre-selected borings or where elevated PID readings were encountered. **Figure 4-4** presents the results of the soil sampling that exceeded the RI screening criteria.

SVOCs / PAHs

The majority of SVOC concentrations exceeding RI screening criteria were located in the former rail spur area at SB-31, SB-26, SB-05, SB-44, and SB-32, with the maximum concentrations observed at SB-32 from 5 to 7 feet bgs. PAHs exceeded the screening criteria in the surficial soil sample collected from 0 to 2 feet bgs at nearly every soil boring.

Samples from SB-32 showed elevated PAH and phthalate concentrations (2-methylnaphthalene and bis[2-ethylhexyl]phthalate) exceeding criteria from 5-7 feet bgs. This soil boring location is about 6 to 8 feet downgradient from a potential UST. The soil had visual staining, noted oils within the soils, and elevated PID results. The PAH and phthalate concentrations at SB-31 also notably exceeded the screening criteria by one to three orders of magnitude. This sample was collected in an area that Primo Auto Body uses to store automobiles. PAHs and the phthalate exceeded their respective RI screening criteria in the samples collected from 20-22 feet bgs at SB-05 and from 20 to 22 feet bgs at SB-35, in addition to the exceedances observed in the respective surficial soil samples.

Polychlorinated Biphenyls, Pesticides, and Mercury

PCB concentrations (Aroclor 1260) exceeding the RI screening criteria (240 µg/kg) were found in three surface soil samples at SB-31, SB-45, and SB-26. The exceedances ranged from 1,200 µg/kg to 100,000 µg/kg, with the maximum concentration observed underneath the warehouse (Lot 33) at SB-45. SB-45 is adjacent to a large sump in the floor of the building at Lot 33; therefore, the contamination is likely not attributed to WACC since this building and the sump was not present during WACC operations. The geophysical survey identified a pipe or a channel leading out of the sump under the concrete heading northwest. SB-31 and SB-26 are located in the former rail spur area.

Concentrations of pesticides (4,4'-dichlorodiphenyltrichloroethane [4,4'-DDT]and dieldrin) only exceeded screening criteria in one sample, at SB-45 from 0-2 feet bgs, collocated with the sample containing the maximum concentration of PCBs.

Mercury concentrations exceeding the RI screening criteria were collocated with the PCB exceedances (SB-31, SB-45, and SB-26) and at three additional locations, SB-44 and SB-05 in the former rail spur area and SB-08 underneath the Primo Auto Shop (Lot 42) building. The maximum concentration of mercury is collocated with the maximum concentration of PCBs at SB-45.

Arsenic and Iron
Arsenic and iron exceeded the screening criteria in every sample collected. Arsenic concentrations ranged from 0.85 mg/kg to 45 mg/kg, exceeding the screening criteria of 0.68 mg/kg. The median value of this range is 3 mg/kg. The two highest arsenic concentrations of 31 mg/kg and 45 mg/kg were found under the building at SB-07 and SB-08. Iron concentrations ranged from 1,300 mg/kg to 26,000 mg/kg, exceeding the screening criteria of 2,000 mg/kg. The median value of this range is 13,000 mg/kg. The two highest iron concentrations of 22,000 mg/kg and 26,000 mg/kg were found in two soils sampling collected from Lot 31 in the former rail spur area. Arsenic concentrations were mostly comparable to background (maximum background concentration of 6.3 mg/kg) except for some outliers. Iron concentrations were comparable to background. This indicates the metals are likely associated with the urban fill or naturally occurring in the glacial soils.

4.4.1.2 Adjacent Properties (Non-Radiological)

308 Cooper Street Soil Borings
Equity Environmental Engineering (Equity) (Equity Environmental Engineering 2016) collected split soil samples for TCL VOCs, SVOCs, pesticides, PCBs, and TAL metals including mercury at soil boring locations SB-56, SB-58, SB-60, and SB-62. Two soil samples were collected from each boring except SB-56, where three samples were collected (Equity 2016). No VOCs were detected above the screening criteria, similar to the samples collected for this RI. PCBs and pesticides were not detected above the RI screening criteria. Numerous SVOCs, including indeno(1,2,3-cd)pyrene, chrysene, benzo(b)fluoranthene, benzo(a)pyrene, benzo(a)anthracene, benzo(k)fluoranthene, and dibenzo(a,h)anthracene, were detected in the majority of samples at concentrations similar to those observed at the WACC property. Some PAHs, including indeno(1,2,3-cd)pyrene and dibenzo(a,h)anthracene, were found at higher concentrations in the 308 Cooper Street borings than those at the WACC. Metals including copper, lead, mercury, and zinc were also detected in all samples at levels within range of or higher than concentrations observed at the WACC property. Copper and lead were found at concentrations higher than those observed at the WACC.

335 Moffat Street Soil Borings
Three samples were collected by the owners' contractor (GFE 2015) at varying depths (19-20 feet bgs, 14-15 feet bgs, and 4-5 feet bgs) at the 335 Moffat Street property for TCL VOCs and TCL SVOCs. Concentrations of VOCs and SVOCs were less than the RI screening criteria. SVOCs were detected in one sample (collected from 4-5 feet bgs). The concentrations were within the lower range of those observed at the WACC property and less than the RI screening criteria.

4.4.2 Radiological Soil Contamination

For simplicity, radiological soil contamination is presented by site areas based on exposure route and property boundaries. The discussion follows the following order:

- Soils Below WACC buildings (Lots 46, 48, 44, 42, and 33)
- Former rail spur area (Lots 30 and 31)
- Adjacent streets and properties – Irving Avenue; Moffat Street, 338-348 and 350 Moffat Street, and 335 Moffat Street; Cooper Street, and 308 Cooper Street

it might be better to separate the Ra from Th values

Each section presents information collected during previous investigations followed by the supplemental data collected during this RI. **Figure 4-5a** presents the combined Th-232 and Ra-226 concentration data, while **Figures 4-5b** and **4-5c** present the separate Th-232 and Ra-226 results, respectively. **Figure 4-6** presents the data in cross-section views. **Tables 4-11, 4-12,** and **4-15** present the soil results.

4.4.2.1 Soils Below WACC Buildings (Lots 46, 48, 44, 42, 33)

of what

The NYCDDC RSS identified contamination in soils under the former kiln-vat building (Lots 44 and 42) down to approximately 20 feet, with concentrations up to 1,100 pCi/g. Waste tailing were observed in the upper four feet of soils; however, a lens of contamination was also identified from 8 to 10 feet bgs, indicating that the tailings may have been buried at the site. This contamination was associated with process liquors, which contain a soluble and mobile form of Th-232, and, therefore, allow the Th-232 to leach down through the soil matrix. In 2013, concrete/lead shielding was installed under Lot 44 and half of Lot 42 (Primo Auto Body) and under a portion of the sidewalk along Irving Avenue. Building material contamination (discussed in Section 4.2.2) was found in bricks collected from Primo Auto Body, which is currently housed in the kiln/vat building that was used to process the monazite sands and extract thorium. In addition to the high levels of soil contamination previously found where the concrete/lead shielding was installed, the floor gamma surveys showed high levels of gamma in the northern corner of Lot 33-1, in Lot 46, and the middle of Lot 33-4, suggesting additional contamination below the floors.

The 2015/2016 RI found surficial soil contamination (0-2 feet bgs) under Lot 46 (Jarabacoa Deli), Lots 42 and Lot 44 (Primo Auto Body and Terra Nova), and Lot 33. The samples collected under Lot 33 (SB-44 and SB-45) had surficial Th-232 concentrations of 54.23 pCi/g and 2.62 pCi/g, respectively, with concentrations below screening criteria in samples collected from 2 to 4 feet bgs and deeper. The corresponding Ra-226 concentrations for SB-44 and SB-45 were 62.83 pCi/g and 0.87 pCi/g, respectively, with concentrations below screening criteria at depth. Historical samples collected at Lot 33 showed similar results. Lot 33 was used as a storage yard for WACC. The widespread surficial soil contamination in Lot 33 is likely attributed to stockpiling of waste tailings or monazite sand which was subsequently covered by the warehouse.

Contamination extends deeper under the former kiln/vat building area where the monzonite processing took place, which is the current location of Primo Auto Body at Lots 44 and 42. Two borings (SB-07 and SB-08) were installed through the lead shielding in this area. Black/gray ash-like material was observed in the soil borings from 0 to 2 feet in this area, similar to soils in the areas of surficial contamination at the site.

SB-07, located under Lot 44, had a Th-232 concentration of 261.2 pCi/g in the surficial soil sample with a corresponding Ra-226 concentration of 6.79 pCi/g. Ra-226 concentrations in soil samples below 4 feet bgs were below screening criteria. However, Th-232 contamination in this borehole extends to 16 feet bgs with a concentration of 15.89 pCi/g from 14 to 16 feet bgs.

The highest Th-232 concentrations observed during the RI were found in SB-08, located below the former storage yard at Lot 42. A Th-232 concentrations over 400 times the screening criterion was observed from 6 to 8 feet bgs, at 533.80 pCi/g. The maximum concentration in this borehole, 759.99 pCi/g, was from 10 to 12 feet bgs. Contamination in this borehole extends down to 22 feet bgs with a Th-232 concentration of 120.44 pCi/g and a Ra-226 concentration of 1.58

pCi/g from 20 to 22 feet bgs. Th-232 concentrations remain above the screening criterion down to 24 to 26 feet bgs with deeper samples having concentrations below the criterion. Both boreholes, SB-07 and SB-08, indicate that the radioactive material migrated downward through the soil, which suggests it was mobilized in the form of thorium process liquors. Thorium dissolved in sulfuric acid (thorium process liquors) was a byproduct of the monazite sands processing which took place in the kiln/vat building.

4.4.2.2 Former Rail Spur Area (Lot 30 and 31)

The exterior gamma investigation for the NYCDDC RSS (LBA 2010) and associated soil sampling indicated that contamination in the former rail spur area was due to surface deposition of tailings. The appearance of the material was black or gray and ash-like. Most contamination in this area was observed in the upper two feet of soils with no contamination observed deeper than the top four feet of soils. Most concentrations were greater than 5 pCi/g but less than 55 pCi/g. A hotspot of contamination was observed adjacent the northern corner of Lot 42. The Th-232 concentrations in the two historic soil borings in this area were 99.5 pCi/g and 471.8 pCi/g. These samples were collected where RI soil boring SB-04 is located. One historic sample collected from 2 to 2.5 feet bgs adjacent to the northern corner of Lot 33 had a Th-232 concentration of 207.8 pCi/g. The NYCDDC RSS (LBA 2010) recommended further work to determine the lateral extent of contamination in this area.

In the RI, gamma surveys were conducted to identify areas for soil sampling. In the former rail spur area, elevated gamma readings were observed adjacent to the WACC buildings in Lot 31. Gamma readings in Lot 30, adjacent to the cabinet maker building (5606 Cooper Avenue), were mostly within background levels or just above background.

Hotspots of elevated gamma readings were observed in the former rail spur near the northern corner of Lot 33, extending adjacent to the WACC buildings to Cooper Street and near the southern corner of Lot 31 adjacent to the Irving Avenue/Moffat Street intersection. Two small hotspots of elevated gamma readings were also observed adjacent to the elevated rail line behind 5606 Cooper Avenue. Soil samples were collected in each hotspot area; the results of the soil sampling are discussed in the subsections below.

Lot 31 (Former Rail Spur Area)

Soil sampling showed contamination is primarily surficial (0-2 feet bgs) with higher concentrations closer to the WACC buildings and in the southern corner of Lot 31 (adjacent to the Irving and Moffat intersection). The surficial contamination is likely due to waste tailings present throughout the area from 0 to 2 feet bgs, as observed in the lithologic descriptions and during previous investigations. Soil borings SB-03 and SB-04, in the northern gamma hotspot adjacent to the northern end of Lot 42 confirmed that the gamma readings were associated with elevated levels of surficial contamination of Th-232 at 43.79 pCi/g in SB-04 and at 7.52 pCi/g in SB-03. The associated Ra-226 concentrations in these two samples were 5.62 pCi/g and 2.15 pCi/g, respectively. These borings are located near the elevated Th-232 concentrations found during the NYCDDC RSS.

Soil borings (SB-31, SB-32, SB-79, SB-82, and SB-83) advanced in the southern portion of Lot 31 adjacent to the Irving Avenue/Moffat Street intersection, showed elevated levels of Th-232 in surficial soil samples between 2 and 15 times the screening criteria. The maximum concentration was 19.34 pCi/g at SB-83.

In these areas radionuclide contamination above the screening criteria was only found sporadically below the surficial soils as shown on **Figure 4-5a**. The maximum concentrations in soils 2 to 4 feet bgs were in two samples collected in soil borings SB-31 and SB-83 with Th-232 at 17 pCi/g and 15.6 pCi/g and Ra-266 at 2.7 and 5.26 pCi/g.

In soils deeper than 4 feet bgs, contamination was just slightly above the screening criteria in borings in the southern Lot 31 area adjacent to the Irving/Moffat intersection. The highest concentration in this area at depths below 4 –feet was 11.95 pCi/g at SB-32.

These RI sample results confirmed historic results collected in the vicinity.

Lot 30 (Cabinet Maker – 5606 Cooper Avenue)
Surficial soil concentrations in Lot 30, near the cabinet maker building (5606 Cooper Avenue), were generally slightly above the screening criteria, with the highest concentration of Th-232 at 2.93 pCi/g and Ra-226 at 1.72 pCi/g in SB-28 from 0 to 2 feet bgs. Concentrations were below the screening criteria in samples collected below 2 feet bgs.

Surficial soil contamination was observed in the railroad area behind the cabinet maker building at SB-81 and SB-80 with Th-232 concentrations at 20.18 pCi/g and 24.95 pCi/g and Ra-226 concentrations at 3.83 pCi/g and 8.26 pCi/g. Concentrations were below background in SB-80 at 2-4 feet bgs and in SB-81 at 1-2 feet bgs. Lateral delineation was not achieved in this area with soil sampling, as the samples were collected in two hotspots with elevated gamma readings. The gamma readings, which have been confirmed by soil sampling data, indicate that the extent of contamination is likely delineated in the railroad area. This contamination is likely due to filling of waste tailings as black/gray ash-like material was observed in the top one foot of soil at these two locations.

4.4.2.3 Irving Avenue, Moffat Street, and Cooper Street

The exterior gamma investigation conducted as part of the NYCDDC RSS, found extensive gamma readings greater than 10 times background at the Irving Avenue and Moffat Street intersection and in the portion of Irving Avenue in front of the WACC buildings, with gamma readings dropping to background at the intersection of Irving Avenue and Cooper Street. Elevated gamma measurements greater than three times background continued to be observed toward the south on Moffat Street and dropped off to background approximately 300 feet from the intersection with Irving Avenue.

Irving Avenue and Moffat Street Intersection
In the RI, the corner of Irving Avenue and Moffat Street had the highest gamma readings outside of the WACC property. The gamma walk-over survey measured readings in the majority of this area above background with some hotspots greater than 20,000 cpm (four times background). Soil samples from a soil boring advanced in the middle of the intersection of the two streets (SB-50) found 209.93 pCi/g of Th-232 and 38.65 pCi/g of Ra-226 in the top 1 foot of soil.

Irving Avenue

Along Irving Avenue, moving westward, the contamination decreases significantly but remains surficial. Ash-like material was observed at SB-01 and SB-02 in the top foot of soil. The surficial soil samples at these locations had Th-232 concentration of 2.58 pCi/g and 3.15 pCi/g, respectively. Ra-226 concentrations in these samples were below the screening criterion. In general, concentrations decreased with depth. However, the sample from 10 to 12 feet bgs at SB-01 had Th-232 at 5.01 pCi/g. Two historical sample locations also indicated deeper contamination in the zone from 16 to 20 feet bgs. The elevated deeper contamination may be due to the disposal of contaminated process liquors in the sewer line in this area that may have leaked to the surrounding soils.

Moffat Street

Gamma readings on Moffat Street generally decreased toward the south, away from the Irving Avenue intersection. Gamma surveys showed elevated readings greater than four times background in front of/adjacent to the 338 Moffat Street building, beginning approximately 70 feet south of SB-50 and extending approximately 150 feet. Moving south on the street through the hotspot of gamma readings, readings increased adjacent to the property building but generally decrease on the west side of the street.

Soil samples on Moffat Street with elevated Th-232 concentrations were generally collected from the upper one to two feet of soil. Only three soil borings had Th-232 above background and two soil borings had Ra-226 above background at depth including SB-35 to 8 feet bgs, SB-34 at 6 feet bgs, and SB-51 at 8 feet bgs. These three samples locations are within 75 feet of the Irving Avenue intersection.

A soil boring targeting the northern edge of this gamma hotspot (SB-35) is shown on cross-section D-D' (**Figure 4-6**). Brick fragments and tailings fill was observed to 8 feet bgs. The sample collected from 2 to 4 feet bgs had Th-232 at 10.06 pCi/g and Ra-226 at 2.34 pCi/g. Th-232 and Ra-226 concentrations generally decreased with depth and were below screening criteria below 8 feet bgs.

Toward the south on Moffat Street, two soil borings located in gamma reading hotspots, SB-36 and SB-51, had elevated surficial Th-232 at 28.55 pCi/g and 59.35 pCi/g and Ra-226 at 5.55 pCi/g and 11.13 pCi/g, respectively. Soil observations at these locations showed potential waste tailings in the top foot of soil. Concentrations decreased with depth, with concentrations below screening criteria in samples below 2 feet bgs in SB-36 and 8 feet bgs in SB-51.

Approximately 40 feet south from the hotspot on Moffat Street, gamma readings drop to just above or within background levels. The gamma survey shows three small areas of elevated counts from two to three times background. Soil observations at each of the four borings showed the presence of waste tailings in the top one or two feet. Soil borings targeting these three areas (SB-38, SB-41, SB-53, and SB-54) had surficial Th-232 sample results of 4.21 pCi/g, 4.37 pCi/g, 19.35 pCi/g, and 39.30 pCi/g, respectively. Ra-226 in these surficial samples was 1.87 pCi/g, 1.84 pCi/g, 5.19 pCi/g, and 6.87 pCi/g. Samples from SB-54 and SB-55, further south on Moffat Street, had Th-232 concentrations below the screening criterion at all depths. Gamma readings south of SB-54 and SB-55 were all within the range of background, delineating the extent of contamination on Moffat Street.

338-348 and 350 Moffat Street

The gamma readings at this property were mostly within background levels. Soil samples collected from borings through the floors of the property buildings showed slightly elevated concentrations of both Th-232 and Ra-226 from 0 to 10 feet bgs, but less than 2 times the screening criteria. The maximum concentrations of Th-232 and Ra-226 were 2.39 pCi/g and Ra-226 1.81 pCi/g, respectively.

Several soil samples were collected to the east of the property buildings; similar to inside the building, Th-232 concentrations were slightly elevated, but less than two times the screening criterion, in a majority of the soil samples. However, toward the northeast corner of the building adjacent to the southern corner of Lot 31, soil gamma readings were elevated with counts greater than four times background. A soil sample collected from 0 to 2 feet bgs in this area at SB-65 had Th-232 at 4.91 pCi/g, and Ra-226 at 3.21 pCi/g, confirming the gamma scan reading. The gamma walk over survey shows a thin line of elevated gamma readings greater than four times background extending from the area of the soil sample to the south. Surficial soil samples at SB-66, SB-67, and SB-68 all contained Th-232 concentrations greater than two times the screening criteria, with the maximum at SB-66 at 2.35 pCi/g. The maximum concentration of Ra-226 was in the surficial sample collected from SB-68 at 1.85 pCi/g. The deepest elevated Th-232 concentration was at 8 feet bgs in SB-67 with a concentration of 2.19 pCi/g. The sample had Ra-226 at 2.39 pCi/g.

These buildings were not present when WACC was in operation. The low levels of soil contamination may indicate that contaminants from the WACC property migrated offsite due to surficial runoff into this area or that contaminated soils were used to grade and fill the area prior to construction of the buildings.

335 Moffat Street

Samples were collected from six soil borings at 335 Moffat Street by the property owner and analyzed for Th-232 and U-238. The maximum Th-232 concentration was 2.62 pCi/g at 5 to 7 feet bgs from the soil boring located underneath the northern portion of the building. The building was built after WACC started production so there is some potential that soils below the building had been contaminated. This sample also had the maximum U-238 concentration at this property at 2.28 pCi/g. Another sample from the northern portion of the property at 1 to 2 feet bgs had Th-232 above the screening criterion at 2.19 pCi/g. These low levels of contamination are potentially due to past surficial runoff from the WACC property.

Cooper Street

Contamination above the screening criteria was observed in soils under Cooper Street near the WACC property. Two samples from 0 to 2 feet bgs on the west side of the street from the WACC property at SB-20 and SB-22 found Th-232 at 2.05 pCi/g in both samples, with Ra-226 at 0.96 and 0.6 pCi/g, respectively. Three historical locations on Cooper Street closer to the WACC property near the former rail spur area detected higher concentrations of combined Th-232 and Ra-226 between 5 and 55 pCi/g. No concentrations were above the screening criteria below 2 feet bgs.

308 Cooper Street

The gamma walk-over survey at 308 Cooper Street showed most of the activity at this property is only slightly above background levels, except the northeastern corner of the property, which had readings at least twice background levels. Results from tSB-56 showed Th-232 and Ra-226 concentrations above the screening criteria at 6.44 pCi/g and 1.67 pCi/g, respectively, in the surficial soil sample. Three other surficial soil samples were above the screening criterion for Th-232 at SB-57, SB-58, and SB-59 with the maximum concentration at SB-57 at 1.49 pCi/g. Five samples at depths ranging from 2 to 26 feet bgs had Th-232 concentrations only slightly greater than the screening criterion, with a maximum concentration of 1.88 pCi/g at SB-60 from 2 to 2.6 feet bgs.

4.4.3 Conclusions of the Soil investigations

- Polycyclic aromatic hydrocarbon (PAH) concentrations exceeding the screening criteria were found throughout the shallow soils at the WACC property. PAHs as deep as 7 feet bgs may be related to former underground storage tanks (USTs) or use of the area to store demolished cars. Similar concentrations were also found at the nearby property, 308 Cooper Street. Polychlorinated biphenyls (PCBs) exceeded the screening criteria by at least an order of magnitude in three locations, with a maximum concentration of 100,000 µg/kg. PCBs in the shallow soils can also be related to USTs or a sump below the building in Lot 33. Arsenic and iron concentrations exceeding the screening criteria were found in all samples at all depths and within the range of background levels, indicating the metals are likely associated with urban fill or the glacial soils.

see section 4.4.2.1

- Under the WACC buildings, radiological contamination above screening criteria extends to a depth of 28 feet bgs under Lot 44, the former kiln/vat building and to 24 feet bgs under Lot 42, the former yard where the monazite sands were loaded into the kiln/vat building for processing. The highest Th-232 concentration observed during the RI was found in SB-08, located in Lot 42, at 760 pCi/g from 10 to 12 feet bgs.

- There is widespread surficial radiological contamination related to surficial runoff/erosion or filling of tailings or monazite sands. Surficial contamination was observed in the former rail spur area, at the intersection of Irving Avenue and Moffat Street, the northern portion of Moffat Street and the eastern portion of Irving Avenue, and in the southeast corner of Lot31/northern part of 350 Moffat (area adjacent to the Moffat/Irving intersection). This contamination was likely due to filling in the area with process tailings or stockpiling the tailings or the monazite sands in the former storage yards without covering, allowing rainwater runoff to transport the sands and tailings to lower topographic areas.

4.5 Results of Sewer Investigation

Sewer investigations were performed within and adjacent to the CSS in the area around the WACC property. Sewer lines throughout the neighborhood that were, or potentially were, connected to the impacted CSS were investigated as well as the CSS discharge point at Newtown Creek. The investigation included:

- Sewer line fiberscope mapping and gamma rate measurements to identify the extent of radiological impacts within the sewers and the potential for contaminated materials to have leaked out of the sewers.

- Sewer manhole gamma scans, construction material and sewer sediment sampling to identify the extent of radiological impacts within CSS manholes.
- Soil borings to sample soils adjacent to the CSS lines to determine if leaking sewers have impacted soils adjacent to the sewer lines and the concentration and extent of contamination surrounding the sewer.
- Sediment samples at the CSS discharge to identify whether contaminated material disposed in the CSS has impacted the sediment at the sewer discharge at Newtown Creek (East Branch).

Data presented in the sections below include the RI data and historic surveys performed by NYCDDC and EPA RST 2.

4.5.1 Sewer Line and Manhole Gamma and Exposure Rate Measurements

An investigation of the sewer line originating at the WACC property was conducted to evaluate the extent of contaminant transport caused by the process waste disposal into the sewer line. Historic investigations were completed in the sewer manholes downgradient of the WACC property. The RI completed a pipeline fiberscope investigation with pipeline gamma scans. Sewer line and sewer manhole investigation data is summarized on **Tables 4-20 and 4-21** and on **Figure 4-7**.

CSS flows away from the WACC property along Irving Avenue toward the west/northwest in the direction of Halsey Street, where it turns north/northeast onto Halsey Street and subsequently turns west/northwest onto Wyckoff Avenue. Sewer lines on adjacent cross-streets (Cooper Avenue, Decatur Street, Covert Street, and Schaefer Street) discharge into the Irving Ave sewer line. Upstream and downstream directions are used in the discussion of the sewer system and are based on the direction of sewer flow.

<u>Previous Investigations</u>

NYCDDC RSS

Gamma measurements collected in the CSS manholes as part of the NYCDDC RSS found the most elevated gamma readings (ranging from 479 µR/hr to 605 µR/hr) in the manholes closest to the WACC property (C-1, I-2, and M-1 [CDM Smith designations I-3, I-5, and I-2], respectively). Table 3-1 from the NYCDDC RSS shows the results of the 2010 measurements (**Appendix A**). The investigation found a generally decreasing trend of gamma readings within the CSS manholes along Irving Avenue moving downstream from the WACC property, with gamma readings dropping to the identified background of 10 µR/hr at the intersection of Irving Avenue and Eldert Street at 17 µR/hr, approximately 0.2 mile downstream from the WACC property. On Cooper Avenue, elevated gamma readings were found in the two manholes adjacent to the WACC property.

The RSS concluded there is layer of contamination eight feet under the intersection of Cooper Street and Irving Avenue that is not detectable from the surface but is detectable through the manhole walls. It should be noted that the wall scraping samples were not high enough to cause the significantly elevated gamma readings.

Neighborhood Radiological Assessment

A previous investigation conducted by BVNA in 2013 (BVNA 2014) assessed the potential radiological impact within and adjacent to the CSS in areas downgradient of the WACC property. Downhole field gamma logging measurements were collected in 15 manholes and in 20 soil borings.

Downhole gamma logging indicated three locations with readings 4 to 12 times the background dose rate of 12 µR/hr. All locations were on Irving Avenue at the intersection of or between Cooper Street or Moffat Street. Gamma measurements collected from the manholes indicated a generally decreasing trend on Irving Avenue westward from the WACC property.

should creek be sampled more extensively

2015/2016 RI

Sewer Pipeline Gamma Measurements

Main Sewer Line

The main sewer line originating in front of the WACC property runs along Irving Avenue toward the west/northwest in the direction of Halsey Street, where it turns north/northeast onto Halsey Street and subsequently turns west/northwest onto Wyckoff Avenue, continuing to eventually discharge to the Newtown Creek Wastewater Treatment Plant. At times of sewer overflow (storms) the sewer discharges to outfall NC-083 into the East Branch of Newtown Creek. The line starts at the manhole designated as I-1 (**Figure 4-7**), in front of the WACC property. During the 2015/2016 RI, the manhole was unable to be found and, therefore, was not inspected. However, an investigation conducted in 2009 (LBA 2010) found the manhole (M-2 in the 2010 report) under a 6-foot by 6-foot section of asphalt which was opened to complete the investigation. The gamma readings at three feet above the road surface of the manhole were 164 µR/hr, while the gamma readings in the manhole 3 feet from the bottom were 26 µR/hr. The depth of the manhole is 9 feet. The report states that the high aboveground gamma at this manhole was due to the extensive layer of thorium-bearing soils found under the asphalt in front of Primo Auto Body.

The RI pipeline investigation began on the Irving Avenue sewer line at I-2. Gamma counts at this location were greater than 100,000 cpm. The fiberscope investigation found a longitudinal crack at I-1, indicating the potential for leakage from the pipeline/manhole in this area. To investigate I-1, the field team used I-2 as an entrance for the fiberscope and gamma probe and moved toward I-1 in the sewer line. However, debris in the pipeline about 15 feet upstream of I-2 was impassable.

The sewer line investigation continued downstream from I-2, but was also limited between I-2 and I-6 due to sediment and sediment blockages, impassable debris, and flooding in the I-4 manhole. However, gamma counts from the limited sewer line that was accessed ranged from 40,000 cpm to 386,598 cpm, generally decreasing from I-2 to I-6, moving downstream from the WACC property.

Between I-6 and I-7 (300 to 450 feet from the WACC property), impassable debris was encountered in both directions. On either side of the debris, gamma counts ranged from 10,000 cpm to 125,908 cpm. In these areas of the sewer, high gamma counts may be caused by the blockages as they would prevent the free flow of the radioactive waste through the sewer line, creating radioactive build-up on the upstream side of the blockages. The blockages would also accumulate contaminated particulate matter in the form of sediments and sludge. Additionally, at

I-4, the pipe increases in diameter from 12-inch clay pipe to 24-inch concrete pipe. This could increase the chances for waste buildup in the sewer as the increase in pipe diameter would slow the velocity of the wastewater.

Moving from I-7 to I-8 (approximately 450 to 600 feet from the WACC property), gamma counts greater than 100,000 cpm were recorded, but began to decline around I-8 to below 100,000 but above 50,000. Downstream of I-8, the gamma counts dropped to less than 50,000 cpm but remained above 20,000 cpm. Downstream of I-9, gamma counts increased up to 100,000 cpm but declined to below 50,000 cpm after I-10. From I-11 to H-3, gamma counts were generally less than 10,000 cpm, with a few sporadic occurrences above 20,000 cpm with a maximum of 74,426 cpm between I-12 and I-13. This is potentially due to the increase in the pipeline diameter from 24 inches to 36 inches at I-13 which would slow the velocity of the wastewater. The fiberscope showed a broken pipe about 18 feet downstream from I-12, between I-12 and I-13. Due to the length of sewer line between H-2 and H-3, the investigation in the downstream direction was terminated.

From manhole H-3 moving downstream to W-1, the gamma readings were elevated with all locations above 28,000 cpm and a maximum at 69,000 cpm. The gamma readings decreased approximately 10 feet downstream of H-3, eventually declining to between 5,700 cpm and 13,000 cpm in the Wyckoff Avenue line from W-1 to W-2 where the investigation ended. When the radioactive waste moved into the Wyckoff Avenue sewer line, the flow rate of the wastewater would have decreased due to the increase in pipe size, potentially allowing contaminated sediment to accumulate in the sewer line.

Sewer Lines Feeding Main Sewer Line

Four sewer lines flow into the main sewer line along Irving Avenue including lines on Cooper Avenue, Decatur Street, Covert Street, and Schaefer Street. These were investigated due to potential movement of contamination upstream (backing up against flow) into these lines during periods of flooding. On Cooper Avenue, four manholes and the associated sewer line were investigated beginning approximately 1,000 feet upstream from the Irving Avenue intersection. Gamma counts were slightly above background beginning in the most upgradient manhole, C-4. The maximum gamma count measured in the sewer line between C-4 and C-1 was 11,563 cpm. Moving from C-1 to I-3, the recorded gamma counts increased to a maximum of 103,496 cpm approximately 12 feet from I-3. This is potentially due to blockages in the Irving Avenue sewer line creating back-ups into the Cooper line.

Gamma counts recorded in the sewer line on Covert Street that feeds the Irving Avenue sewer line were all within the range of background with the highest recorded gamma count at 4,700 cpm. An investigation for the sewer line on Decatur Street was unable to be performed; the line was filled with water, likely due to a blockage. An investigation was conducted on the sewer line on Schaefer Street from the I-8 manhole. The gamma readings were all below 5,000 cpm. The investigation ended 37 feet upstream of I-8 in the direction of S-1 due to the presence of debris.

Other Sewer Lines

Two other sewer lines flowing away from the WACC property area were investigated for possible contamination. One sewer line flows south down Moffat Street then turns onto Knickerbocker Avenue while the other flows south down Cooper Street. The two lines are joined at the intersection of Knickerbocker Avenue and Cooper Street. The M-1 manhole shown on **Figure 4-7** was not found. The sewer line going upstream from M-2 on Moffat Street was capped, preventing a survey in this northward direction toward the WACC property. The sewer line survey progressed downstream from M-2 toward M-4; gamma readings varied from background to slightly above background with the maximum reading at 6,013 cpm. Gamma readings From M-4 to the Knickerbocker intersection at K-3, ranged from 1,600 cpm to 4,600, all within the range of background values.

Sewer Manhole Gamma Counts and Gamma Exposure Rate Measurements
Table 4-7 presents the gamma counts and gamma exposure rates collected from the investigated manholes. At each manhole along the sewer lines selected for the investigation, the manhole cover was removed and a one-minute count was taken at the surface with a 1x1 inch NaI detector (Ludlum 44-2 probe/2221 meter) and an exposure rate measurement was taken with a Ludlum Model 9DP.

Gamma readings were collected at the ground surface of the manhole, three feet from the bottom of the manhole, and at the point of the highest reading. The maximum gamma reading was collected from manhole I-5 at 482,397 cpm. The most elevated readings were found in manholes I-2 though I-11, confirming results from previous reports that elevated levels begin to decrease approaching the intersection of Irving Avenue and Eldert Street. These data also align with the gamma readings collected from inside the sewer lines. Elevated readings were also recorded in manholes H-3 and W-1, where elevated sewer line gamma readings were also observed.

Exposure rates were collected at the ground surface of the manhole with the manhole lid open. In general, readings collected at the ground surface with the manhole open were above background (12 µR/hr) in manholes I-2, I-3, I-5 through I-10, and H-2. In sewers where entry was made for material sampling (I-2 and I-4 through I-8), exposure rates also were collected near the bottom of the sewer. The highest exposure rate recorded was in manhole I-5 at 310 µR/hr three feet from the bottom and 39 µR/hr at the ground surface.

4.5.3 Sewer Materials Sampling

Sediments and manhole construction materials were collected from impacted manholes during the RI and previous investigations.

state that gamma not from Th-232

Previous Investigations

One sample of sewer materials was collected as part of the NYCDDC RSS (LBA 2010). A composite sample was collected from M-1 (CDM Smith's I-2) of the sediment on the bottom of the manhole and from "scrapings" on the wall for laboratory analysis. Th-232 was detected at 81.3 pCi/g. This manhole had one of the highest gamma measurements during LBA's investigation gamma survey. Therefore, the report discussed the possibility of contamination present outside of the sewer vault in the form of contaminated fill or from leaky sewer pipes.

Sewer sediment sampling conducted by BVNA (2014) found all samples in the Irving Avenue manholes contained radioactivity above two times the screening criteria (0.92 pCi/g). Samples were collected from 15 manholes along the CSS on the Irving Avenue corridor. Sediment radioactivity was highest in the sample collected from the manhole CDM Smith designated I-5, with a Th-232 concentration of 1,460 pCi/g and a Ra-226 concentration of 72 pCi/g. The lowest sediment measurement was from the manhole CDM Smith designated I-8, with Th-232 at 1.23 pCi/g and Ra-226 at 0.27 pCi/g. However, one of the highest gamma logging measurements was collected at this manhole. Two sewer brick/mortar samples were collected from MH-15 (CDM Smith I-12) and MH-11 (CDM Smith I-2) with Th-232 concentrations of 1.34 pCi/g and 12.4 pCi/g, respectively.

is this background? this is less than 2x background in section

2015/2016 RI

During the RI, sewer material samples, including brick, concrete and cast iron, and sediment and muck (scrapings) were collected from six sewer vaults along Irving Avenue. Sampling locations were selected based on the location of the highest gamma counts and material type. **Table 2-10** presents a summary of the sewer material sampling locations. **Table 4-14** presents the sewer material sampling results.

Construction materials at I-2 and I-4 and sewer sediments at I-2, I-5 and I-7 had elevated concentrations of Th-232 and Ra-226 that are likely causing the elevated gamma readings and gamma exposure rates in these manholes.

- **I-2 (in-manhole gamma reading of 113,646 cpm)** - A brick sample collected three feet from the bottom of the manhole vault, near the incoming sewer line from manhole I-1, had a Th-232 concentration of 2,206.4 pCi/g and a Ra-226 concentration of 76.4 pCi/g. The sediment sample collected from I-2 had elevated laboratory results for Th-232 at 1,079.9 pCi/g and Ra-226 at 69.8 pCi/g for the sediment bottom and 1,218.1 pCi/g of Th-232 and 45.9 pCi/g of Ra-226 for the soft material coating walls of the sewer vault (muck).

- **I-4 (in-manhole gamma reading of 20,964 cpm)** - Elevated concentrations were detected in the degraded cast iron sewer pipe material with Th-232 at 2,536.2 pCi/g and Ra-226 at 163.13 pCi/g. This was the highest result of all sewer samples. The concrete sample in this location was three orders of magnitude less than the cast iron, at 4.4 pCi/g of Th-232 and 2.1 pCi/g of Ra-226.

  how is this explained?

- **I-5 (in-manhole gamma reading of 482,397 cpm)** - A concrete sample was collected due to the elevated gamma reading. The concrete had a Th-232 concentration of 4.67 pCi/g and a Ra-226 concentration of 1.1 pCi/g. The sediment sample collected in this manhole during the BVNA investigation had a Th-232 concentration of 1,460 pCi/g.

- **I-7 (in-manhole gamma reading of 42,843 cpm) -** The laboratory results for the sediment sample had Th-232 at 116.72 pCi/g and Ra-226 at 6.1 pCi/g, one order of magnitude less than at I-2 and I-5, both located upstream and closer to the WACC property.

Based on a comparison of the laboratory results and the gamma count measurements collected in the field, the laboratory results support the gamma count measurements.

4.5.4 Sewer Soil Borings

Previous Investigations

A previous investigation conducted by BVNA (BVNA 2014) targeted sampling for soils, sediments, and materials within and adjacent to the sewer line. Twenty soil borings were advanced adjacent to sewer lines, with four in a background area. Downhole gamma measurements were collected inside the soil borings. Three locations had elevated readings including one in front of the WACC building from 0 to 5 feet bgs and at 17 feet bgs and two other locations from 0 to 4 feet bgs at the intersection of Irving Avenue and Moffat Street and at the intersection of Irving Avenue and Cooper Street. The soil sample results showed one location with significant radioactivity above background: south of the WACC building, at a depth between 15 and 18 feet bgs. This location is near RI soil boring SB-01, which had Th-232 levels greater than five times background from 10 to 12 feet bgs and greater than three times background from 0 to 2 feet bgs.

2015/2016 RI

To determine if radioactive material exists in the soil surrounding the sewer lines, sewer soil borings were performed using DPT at nine locations along Irving Avenue, Cooper Avenue, and Halsey Street. The boring locations were selected based on elevated, in-sewer gamma readings recorded during the fiberscope investigation. **Figure 4-7** presents the results of the sewer soil borings.

Th-232 was detected above its screening criterion in eight samples while Ra-226 was detected above its screening criterion in two samples. Th-232 concentrations were less than two times background at SW-SB-02 from 0 to 2 feet bgs, SW-SB-04 from 4 to 6 feet bgs, SW-SB-06 from 6 to 8 feet bgs, and SW-SB-08 from 4 to 6 feet bgs. SW-SB-02 is located at the intersection of Irving Avenue and Cooper Street, near an historic boring with elevated gamma readings from 0 to 4 feet bgs (BVNA 2014). Soil lithologic observations from this borehole did not indicate the presence of waste tailings.

The maximum Th-232 and Ra-226 concentrations of the sewer soil borings were detected at SW-SB-03 from 0 to 1 foot bgs with concentrations of 58 pCi/g and 7.77 pCi/g, respectively. SW-SB-03 is approximately 100 feet west of the Irving Avenue and Cooper Street intersection. The shallow nature of this contamination indicates it was not caused by leaking from the sewer. It was likely caused by filling of tailings from the WACC property as the soil boring indicated the presence of probable waste tailings in the upper foot of soils.

4.5.5 Sewer Discharge Sediment Sampling

Eight vibracore sediment sampling locations were advanced near the outfall where the sewer line for WACC discharges. Outfall NCB-083 is very large, with flow diverted to this outfall only during CSO overflow during large storms. Discrete sediment samples were analyzed to determine if radioactive material historically discharged in the sewers at WACC has impacted sediment in Newtown Creek. Sediment samples were also collected in Coney Island Creek to serve as a background data set as described in **Section 4.1.4.5**. **Figure 4-8** shows the results of the sampling.

sediment? depth?

The majority of samples collected in Newtown Creek were above the RI screening criterion for Th-232 (0.637 pCi/g); fewer were above the criterion for Ra-226 (0.797 pCi/g). Of the eight locations, five surficial sediment samples had Th-232 concentrations below the RI screening criteria. Sediment collected at the closest locations to the large outfall (EB-01, EB-02, EB-03, and EB-05) had Th-232 concentrations greater than five times the screening criterion (background). The maximum Th-232 concentrations were at EB-01 with Th-232 at 70.211 pCi/g from 5 to 6 feet bgs. This location also contained the maximum Ra-226 concentration at 3.65 pCi/g from 4 to 5 feet bgs. In general, elevated results were isolated to depths of 2 to 8 feet bgs. Elevated Th-232

need clarification

and Ra-226 concentrations at EB-01 were detected from 3 to 7 feet bgs. Elevated Th-232 concentrations at EB-02 were detected from 0.5 to 5 feet bgs and at EB-03 from 0 to 10 feet bgs.

Elevated Th-232 concentrations at depth could be attributed to the historic disposal of the radioactive material impacting Newtown Creek. However, given the nature of the flows into the area, it is impossible to state with certainty based on the data.

if no other facility used Th-232, then why is it impossible to determine if WACC was the culprit?

4.5.6 Conclusions of the Sewer Investigation

- Radionuclide contamination is significantly elevated in the manholes south of the WACC buildings on Irving Avenue where process liquors containing thorium were likely discharged. The elevated gamma levels (>20 times background) continue in the sewer line and manholes on Irving Avenue for approximately two blocks.

- Radionuclide contamination within the CSS is present near the WACC property in sediments/sludge and materials comprising the sewer pipes and manholes. The maximum radionuclides concentrations in sewer materials were found in manhole I-4, located near the intersection of Irving Avenue and Cooper Avenue, with Th-232 at 2,536.2 pCi/g and Ra-226 at 163.1 pCi/g. The maximum Th-232 concentration in sewer sediments was observed in manhole I-2, located south of the WACC property on Irving Avenue, with Th-232 at 1,218.1 pCi/g and Ra-226 at 45.9 pCi/g.

- Gamma scan levels generally drop to four times background at the intersection of Irving Avenue and Schaeffer Street and drop to background at the intersection of Irving Avenue and Eldert Street, with sporadic occurrences of gamma levels above four times background continuing in the sewer along Halsey Street to Wyckoff Avenue.

- Radionuclide contamination appeared limited to the interior of the sewers as soil borings installed adjacent to the sewer lines found only limited radionuclide contamination. A data gap does remain since the fiberscope survey showed potential for exfiltration via breaks in the pipeline along Irving Avenue, indicating that the bedding material below the sewers may be contaminated.

- Radionuclide concentrations in sediment at the Newtown Creek outfall were above screening criteria with a maximum concentration of 70.2 pCi/g from 5 to 6 feet bgs. Samples exceeding criteria were limited to the area immediately adjacent to the outfall discharge.

4.6 Results of Hydrogeologic Investigation

This section provides the nature and extent of contamination in groundwater.

4.6.1 Monitoring Well Sampling

Two rounds of groundwater samples were collected from five monitoring wells for TCL VOCs, SVOCs, Pesticides/PCBs, TAL metals and mercury (total and dissolved), gamma spectroscopy and isotopic radium and thorium. Results for Rounds 1 and 2 that exceeded screening criteria are shown on **Figure 4-9**. A round 3 sampling event was conducted in November 2016 to confirm the radiological results observed during round 2. The round 3 results are pending.

4.6.1.1 Non-Radiological Groundwater Contamination

During Rounds 1 and 2 of sampling four VOCs including chloroform, cis-1,2-dichloroethene (DCE), tetrachloroethene (PCE), and trichloroethene (TCE) exceeded the screening criteria. PCE was significantly elevated in all five wells and the highest concentrations were in wells on the upgradient side of the WACC property. The maximum concentrations of PCE (930 µg/L) and TCE (7.7 µg/L) were in MW-04. The maximum concentration of cis-1,2-DCE (25 µg/L) was in MW-02, located south of the WACC property on Irving Avenue.

However, chlorinated VOCs were not detected in the soil samples at the site, including those from each borehole prior to well installation where samples were collected or screened down to the water table. Additionally, the Phase I report did not indicate the presence of materials currently or in the past that would be associated with chlorinated VOCs. Therefore, it is likely that this contamination may be from an upgradient source.

4.6.1.2 Radiological Groundwater Contamination

During the Round 1 groundwater sampling event, no detections of Th-232 or Ra-226 were observed.

During the Round 2 groundwater sampling event, Th-232 was detected in one sample, at MW-05, at a concentration of 11 pCi/L. However, soil contamination was not detected deeper than 28 feet bgs, and since the groundwater table at the site is at approximately 60 feet bgs, and the surface in the area is mostly impervious and does not readily allow infiltration, it is unlikely that the radionuclide soil contamination at the site caused any groundwater contamination. In order to better understand the nature of this detection, confirmation samples were collected in November 2016; the results are pending.

4.6.2 Perched Groundwater Sampling at 335 Moffat Street

One groundwater sample was collected at 335 Moffat Street within a perched groundwater zone at about 10-feet bgs. The sample was only analyzed for VOCs, none of which were detected.

4.7 Results of Gamma Exposure Rate Confirmation Survey

Previous investigations evaluated the gamma exposure rates related to contamination from the WACC property. The RI conducted gamma exposure rate surveys to confirm the results of the previous investigations. **Figures 4-10a, 10b, and 10c** present the results of the exposure rate surveys.

4.7.1 Exposure Rate Surveys

Previous investigations showed elevated exposure rates near the WACC property in the portion of Irving Avenue south of the WACC buildings, at the intersection of Irving Avenue and Moffat Street, and in the former rail spur area. Gamma background measurements collected during the BVNA investigation (BVNA 2014) ranged from 9 to 12 µR/hr. Interior measurements collected by LBA (2010) found high levels of gamma radiation (between 20 and 500 µR/hr) in the kiln vat building, now Lot 44, and in the WACC yards and other buildings, now Lot 42.

Pre-shielding measurements collected by Weston (2014) found gamma levels above background in Lots 42, 44, and 46, the former rail spur area, and the Irving Avenue sidewalk immediately south of the WACC buildings, specifically in front of Lots 42 and 44. Post-shielding measurements showed significant reductions in the gamma radiation by several orders of magnitude; however, gamma measurements above background were still found in each area. The NRA found background gamma readings throughout the neighborhood around the WACC property, except for one isolated area in south of 11-03 Irving Ave, which is one block west of the WACC buildings on Irving Avenue. Within the area of the WACC building, the neighborhood assessment found elevated gamma readings up to 470 μR/hr on the Irving Avenue asphalt and sidewalk in front of the WACC buildings and on Moffat Street near the WACC buildings.

In 2015/2016, CDM Smith collected gamma exposure rate data to confirm the data collected in previous investigations. **Figure 4-10a** shows gamma exposure rates collected three feet above ground level from the neighborhood area around the site. **Figure 4-10b** shows exposure rates collected three feet above ground level from the exterior areas of the WACC property area and inside the WACC buildings including the deli basement and the first floor. The second floor was inaccessible. Gamma exposure rate measurement locations and results are presented in **Table 4-22**.

4.7.1.1 Neighborhood

The results of the confirmatory investigation in the neighborhood were similar to the past measurements. The results are presented on **Figure 4-10a**. Half of the gamma exposure rates (10 of 20 measurements) collected in the neighborhood, outside the WACC property, were within the range of background levels (9 to 12 μR/hr). The isolated elevated reading previously found in front of 11-03 Irving Ave was confirmed by the confirmatory measurements at 49 μR/hr. The remaining locations above background were located on Moffat Street with the maximum gamma exposure rate approximately 175 feet south of the WACC property. Moving south on Moffat Street, away from the WACC property, gamma exposure rates dropped to background approximately 600 feet from the WACC property. An area of measurements slightly above background ranging from 13 to 17 μR/hr was observed at the intersection of Wilson Avenue and Moffat Street and one block west of the intersection on Wilson Avenue. In previous investigations, gamma exposure rates in this area were slightly below 12 μR/hr.

4.7.1.2 Interior

The results of the WACC exterior and interior investigation (**Figure 4-10b**) were similar, confirming the measurements collected in previous investigations. The interior of the WACC buildings had exposure rate measurements above three times background in the northern corner of Lot 33-1, in Lot 42, Lot 44, and in the basement of Lot 46 along the wall bordering Lot 44. Levels within two and three times background were also found in Lot 33-4. All buildings on the property had gamma exposure rates above background.

4.7.1.3 Exterior

In the exterior portions of the WACC property, the highest gamma exposure rates were found on Irving Avenue south of Lot 42 and Lot 33-1 (**Figure 4-10b**). Closer to the building, the gamma exposure rates dropped significantly due to the presence of lead shielding, but were still above background. Other gamma exposure rates above background were located south across Irving Avenue on the sidewalk, the intersection of Irving Avenue and Moffat Street, immediately south of Lot 33-4, and the northern area of the former rail spur area.

4.8 Results of School and Daycare Investigation

An investigation was conducted at a nearby school and daycare to evaluate the potential presence of contamination in the soil, the gamma exposures potentially impacting people at the property, and the radon and thoron concentrations in the buildings.

4.8.1 School Soil Borings (SCSB-01 through SCSB-06)

Six soil borings were advanced around P.S./I.S. 384 along Moffat Street, Wilson Avenue, and Cooper Street to determine if radioactive material is present in the subsurface near the school. Twenty-four of the 30 samples were just slightly above the RI screening criterion for Th-232 (1.22 pCi/L) with a maximum concentration of 1.55 pCi/L at SCSB-03 from 6 to 8 feet bgs. The highest Th-232 concentrations, between 1.29 and 1.55 pCi/g, were in SCSB-01 through SCSB-03, all located in the sidewalk along Moffat Street. These concentrations just slightly above the RI screening criteria (developed using background data) likely are not representative of contamination due to the WACC property since there is very limited contamination in the soils and sewers on Moffat Street within 600 hundred feet north of this area. These concentrations are more likely due to varied fill material in the subsurface in this area with naturally occurring higher radionuclide concentrations. The surface soil samples at these locations are all below the RI screening criteria. Ra-226 was not detected above the screening criterion.

4.8.2 Exposure Rate Surveys

Exposure rates were taken in the basements and outdoor play areas of P.S./I.S. 384 and the Audrey Johnson Daycare. **Figure 4-10c** presents the results of the exposure rate measurements. In the basements, readings were taken at a minimum every 100 square meters and at least one in every room. In the outdoor play areas, readings were taken every 100 square meters on a 10-meter by 10-meter grid. The exposure rate was then recorded as the average of the readings. All readings were taken at waist height or approximately three feet above the ground surface.

School

Exposure rates measured at P.S./I.S.-384 ranged from 6 to 11 µR/hr and all within or below the background observed for the neighborhood (9-12 µR/hr).

Daycare

Exposure rates measured at the daycare ranged from 8 to 13 µR/hr and all within or below the background observed for the neighborhood (9-12 µR/hr).

4.8.3 Radon and Thoron Evaluations

Short-term air samples were collected in charcoal canisters for radon analysis in the school and the daycare located on Moffat Street south of the WACC property. Long-term samples for 6 and 12 months duration for radon and thoron were collected using ATDs placed inside the school. **Tables 4-23, 4-24, and 4-25** present the short-term, 6-month and 12-month air sampling data, respectively.

School

Short-term radon measurements in the school ranged from 0.1 ± 0.2 pCi/L to 0.4 ± 0.3 pCi/L. The location of the maximum radon level is on the first floor in Classroom 150 and did not exceed the radon first floor screening criterion (0.4 pCi/L). No radon samples were collected in the basement for short-term measurements.

The six-month average radon measurements evaluated using ATDs ranged from 0.2 ± 0.02 pCi/L to 1.3 ± 0.07 pCi/L. The three radon samples in the basement exceeded their screening criterion of 1.2 pCi/L. Six-month average measurements for thoron were detected in two samples at 0.1 pCi/L and 0.2 pCi/L; one was equal to and one exceeded the screening criteria 0.1 pCi/L. The maximum average radon and thoron measurements were both collected in the basement hallway at the same location.

The year average radon measurements ranged from 0.1 pCi/L ± 0.01 pCi/L to 1.2 pCi/L ± 0.05 pCi/L. No samples exceeded the screening criteria; however, one sample collected in the basement was equal to the screening criteria. Year-long average measurements for thoron were detected in one sample at 0.1 pCi/L which is equal to the screening criteria.

Daycare

Radon levels measured at the daycare ranged from 0.2 ± 0.2 pCi/L to 0.7 ± 0.2 pCi/L. The maximum radon level was measured on the first floor in Room 4 and exceeded the first-floor radon screening criterion (0.4 pCi/L).

Section 5

Contaminant Fate and Transport

An evaluation of the fate and transport of contamination was performed to identify the mechanisms and pathways by which radionuclides present at the site could be released from their current locations, move through environmental media, and potentially impact human and ecological receptors. The evaluation is based on chemical properties of the radionuclides, the source of the radionuclides, and the physical characteristics of the site. This section includes:

- A summary of the selection of the principal radionuclides
- A summary of the relevant physical-chemical properties and mobility of the contaminants
- A discussion of processes that affect the fate of contaminants in the environment
- A discussion of processes that affect transport potential of contaminants
- A summary of the fate and transport evaluation
- A presentation of the CSM

5.1 Selection of Principal Contaminants

Section 4 discussed the nature and extent of contaminants focusing on those that most frequently exceeded screening criteria. This included the following:

- Radionuclides found in all media throughout the site
- PAHs in soil
- PCBs in soil
- PCE, TCE, and cis-1,2-DCE in groundwater

Ra-226

Th-232

Section 5 will focus on principal radionuclides (thorium and radium ~~which is the decay progeny of uranium~~), which are associated with historic site practices, were found in previous investigations, and most frequently detected above the screening criteria.

The other contaminants are not discussed in the fate and transport section because these chemicals were either not likely related to the WACC processes or were limited in their extent or magnitude of contamination.

5.2 Physical and Chemical Properties Influencing Contaminant Fate and Transport

don't you mean Ra-226
although U-238 is the parent?

Based on the nature of operations at the site, significant amounts of thorium and uranium were introduced to the soils from the monazite sands and byproducts from the processing of the monazite sands including tailings and process liquors. The monazite sands and tailings were likely stockpiled in the former storage yards while the process liquors were disposed to the CSS. Tailings were also likely buried on site. The presence of high concentrations of thorium in the surface soils indicates that most thorium has been retained in the shallow soil.

Thorium

Thorium, a metallic element of the actinide series, is a naturally-occurring radioactive substance. In the environment, thorium exists in combination with minerals such as silicate minerals. Small amounts of thorium are present in all rocks, soil, water, plants, and animals. Soil contains an average of approximately 6 parts per million (ppm) of thorium. Some rocks in underground mines contain thorium in a more concentrated form. After these rocks are mined, thorium is usually concentrated and changed into thorium dioxide or other chemical forms.

Thorium occurs in nature in four isotopic forms: Th-228, Th-230, Th-232, and Th-234. Thorium, like all radioactive materials, is not stable and breaks down through a decay chain/series of decay products until a stable product is formed. During these decay processes, radioactive substances are produced including radium and radon. These substances give off radiation, including alpha and beta particles and gamma photons. Th-228 is the decay product of naturally occurring Th-232, and both Th-234 and Th-230 are decay products of natural U-238. Of these naturally produced isotopes of thorium, only Th-228, Th-230, and Th-232 have long enough half-lives to be environmentally significant. More than 99.99 percent of natural thorium is Th-232; the rest is Th-228 and Th-230.

Uranium

Uranium is also a metallic element of the actinide series, a naturally occurring radioactive substance. Uranium has the highest atomic mass of any naturally occurring element. In its refined state, it is a heavy, silvery-white metal that is malleable, ductile, slightly paramagnetic, and very dense. In nature, it is found in rocks and ores throughout the earth. In its natural state, uranium occurs as a component of several minerals, such as carnotite and uraninite, but is not found in the metallic state.

Uranium may also be introduced into the environment as a result of mining and milling activities, by uranium processing facilities, or by burning coal.

Natural uranium is a mixture of the three isotopes U-234, U-235, and U-238. All three are the same chemical, but they have different radioactive properties. The only mechanism for decreasing the radioactivity of uranium is radioactive decay. Because all three of the naturally occurring uranium isotopes have very long half-lives (U-234 = 2.5×10^5 years; U-235 = 7.0×10^8 years; and U-238 = 4.5×10^9 years), the rate at which the radioactivity diminishes is very slow (National Council on Radiation Protection and Measurements [NCRP] 1984). Therefore, the activity of uranium remains essentially unchanged over periods of thousands of years.

By weight, natural uranium is approximately 0.01 percent U-234, 0.72 percent U-235, and 99.27 percent U-238. Approximately 48.9 percent of the radioactivity is associated with U-234; 2.2 percent is associated with U-235; and 48.9 percent is associated with U-238. The shorter half-life makes U-234 the most radioactive, while the longer half-life makes U-238 the least radioactive.

Essentially, U-234 will be approximately 20,000 times more radioactive and U-235 will be 6 times more radioactive than U-238 (ATSDR 2013).

When U-238 gives off its radiation, it decays through a series of different radioactive materials, including U-234. This series, or decay chain, ends when it reaches the stable, non-radioactive element lead.

Radium

Radium is a naturally occurring, silvery-white, radioactive metal that can exist as several isotopes. Usually, natural concentrations are very low. However, weathering and other geologic processes can form concentrated deposits of naturally radioactive elements, especially uranium and radium. Radium in soil and sediment does not biodegrade or precipitate in any chemical reactions that alter it into other forms (ATSDR 1990). The only degradation mechanism in air, water, and soil is radioactive decay.

Radium forms when isotopes of uranium or thorium decay in the environment. As a decay product of uranium and thorium, radium is common in virtually all rock, soil, and water. Radium's most common isotopes are Ra-224, Ra-226, and Ra-228. Ra-226 is found in the U-238 decay series, and Ra-228 and Ra-224 are found in the Th-232 decay series. Ra-226, the most common isotope, is an alpha emitter, with accompanying gamma radiation, and has a half-life of approximately 1,600 years. Ra-228 is principally a beta emitter and has a half-life of 5.76 years. Ra-224, an alpha emitter, has a half-life of 3.66 days (EPA 2009). Radium decays to form isotopes of the radioactive gas radon, which is not chemically reactive. Ra-226 decays by alpha particle radiation to an inert gas, Rn-222, which also decays by alpha particle radiation and has a short half-life of 3.8 days. Ra-224 decays by alpha particle radiation to form Rn-220 (thoron), which also decays by alpha particle radiation and has an even shorter half-life of 55 seconds. Stable lead is the final product of this lengthy radioactive decay series.

Physical and Chemical Properties of the Radionuclides

The fate, persistence, and potential transport of the radionuclides are dependent on the physical and chemical properties of the metals (**Table 5-1**), the properties of the medium through which they migrate, and the environmental conditions to which they are exposed.

5.3 Contaminant Fate

Chemical and physical properties that affect the fate and transport of the radiological contaminants include water solubility, speciation, partitioning and sorption, and degradation (or decay) rate. These properties are generally interrelated and are a function of a number of other variables including oxidation-reduction potential, pH, temperature, and the type and concentration of other chemicals capable of bonding with metal ions (e.g. natural organic matter).

Precipitation and Dissolution

Dissolution is the partitioning of a chemical in the liquid phase. Precipitation is the process of precipitating or changing the solution to a solid. Precipitation and dissolution reactions are government by the solubility of the thorium and uranium and the kinetics of the precipitation/dissolution processes. Solubility of a chemical depends on the solution. Solvation, as defined by the International Union of Pure and Applied Chemistry, is an interaction of a solute with the solvent, which leads to stabilization of the solute species in the solution. Water solubility is the maximum concentration of a chemical that dissolves in a given amount of pure water at a specific temperature and pH. Pure thorium and uranium are insoluble in water; however, complexes with the metal have differing solubilities. Highly insoluble contaminants are unlikely to leach from soil into groundwater and from sediments into surface water. The solubility of chemicals that are not readily soluble in water, such as thorium and uranium, can be enhanced in the presence of organic solvents or under acidic conditions.

Sorption and Partitioning

Partitioning is the distribution of chemicals between a solid such as soil or sediment, liquid, and gas. Sorption is the tendency for contaminants to adsorb to materials in the environment. The degree of sorption is a function of the chemical properties of the contaminant as well as the properties of the media through which the contaminant moves. The presence of organic carbon in the soil, aquifer matrix, or sediment will facilitate the adsorption of compounds.

One type of partitioning coefficient, the partitioning distribution coefficient (K_d), is important in predicting the behavior and mobility of radionuclides in the environment. The K_d value is the ratio of the concentration of a chemical in a solid phase to the corresponding aqueous-phase concentration. The K_d measures the relative mobility of a chemical in the environmental. A high K_d value implies that the contaminant is tightly bound to the soil and will migrate slowly. The most important variables affecting K_d are pH and salinity of water, grain size, and mineralogy of the soil, concentration of competing ions present, and the organic carbon content of the soil.

Table 5-1 shows the wide range of K_d values for the principal contaminants based on literature values. The wide range of K_d values signifies the variation of the radionuclides partitioning between two immiscible phases at equilibrium, the variation in partitioning tendencies in different solutions, and the complexity of the natural environment being replicated with experiments.

Speciation

The fate and transport of metals is primarily driven by chemical speciation. The speciation of an element is determined by defining the chemical form (oxidation state, charge, proportion and nature of the complexed forms) and sometimes the physical form (distribution among soluble, colloidal or particulate forms, and solid phases) in which it occurs (Moulin et al. 2005). Factors influencing speciation include pH, oxidation-reduction potential, ionic strength, and the types and concentrations of ligands and complexing agents. Metals can exist as cations, anions, or neutral species. Their sorption, solubility, and mobility depends on their ionic form.

Radioactive Decay Rate

The decay rate of a radionuclide is expressed in terms of a radionuclide-specific half-life and can be on the order of days, weeks, or years. The half-life of a radioactive substance is the time in which half of the atoms are transformed to another substance or daughter product. Radioactive decay affects the environmental persistence of radionuclides. Decay of radionuclides occurs by the emission of alpha particles (a combination of two protons and two neutrons) and beta particles (negatively charged high-speed electrons). Decay of many radionuclides is accompanied by the emission of gamma rays. The first radionuclide on the decay chain is called the parent compound. The parent compounds of important at the site are Th-232 and U-238. These parent radionuclides each yield radioactive decay products. Under normal conditions, radioactive decay is independent of any physical or chemical process.

5.3.1 Thorium

The fate and mobility of thorium in soil are governed by sorption and the properties of the soil including pH, ORP, porosity, soil particle size and sorption properties. In most cases, thorium will remain strongly adsorbed to soil and its mobility will be very slow (Torstenfelt 1986). The leaching of thorium to groundwater will not occur in most soils. The presence of ions or ligands (i.e., carbonate ion or humic matter) that can form soluble complexes with thorium are expected to increase thorium's mobility in soil. Normally, thorium compounds will not migrate long distances in soil and will persist in sediment and soil (ATSDR 1990a).

The solubility of thorium in water is low and, therefore, its mobility in water is low. In water, thorium will most likely be present adsorbed to suspended matter and sediment and the concentration of soluble thorium in water will be low (Hunter et al. 1988; Sheppard 1980). The concentration of dissolved thorium in water may increase due to the formation of soluble complexes with carbonate, humic materials, or other ligands in the water (LaFlamme and Murray 1987). Soluble thorium ions that may be present in low pH conditions would hydrolyze at pH values above 5 to form hydroxy precipitates or complexes; these complexes would be adsorbed on particulates (Milic and Suranji 1982; Bodek et al. 1988; Hunter et al. 1988).

Table 5-1 provides a range of predicted site-specific K_d values for thorium based on two important parameters affecting thorium adsorption: soil pH and dissolved thorium concentrations (EPA 1999). The range of K_d values listed for the pH range of 5 to 8 on EPA's lookup table (1,700 – 300,000 milliliters per gram [mL/g]) is appropriate since it is assumed that soils at the site have a neutral pH. The range of K_d values listed for pH less than 3 is appropriate in areas of potential sulfuric acid disposal. Sulfuric acid has a pH less than 3 standard units (SUs). Since the soils at the site are sandy silts and gravels, it is likely that the K_d value is an average of the range. The K_d value is high, indicating that thorium would likely adsorb to the soil except in areas where the pH of the soil is significantly lowered by the disposal of sulfuric acid with the thorium.

5.3.2 Uranium

The mobility of uranium in soil and its vertical transport (leaching) to ground water depend on properties of the soil, as well as on the amount of water available (Allard et al. 1982). The sorption of uranium in most soil is such that it may not leach readily from surface soil to groundwater. However, geological materials such as silica, shale, and granite have poor sorption characteristics (DOE 1992; Erdal et al. 1979; Silva et al. 1979; Ticknor 1994).

Redox conditions are important in the geologic transport and deposition of uranium. Oxidized forms of uranium (uranium in the +6 valence state [U(VI)]) are relatively soluble and can be leached from rocks and migrate in the environment. When strong reducing conditions are encountered (e.g., presence of carbonaceous materials or hydrogen sulfide), precipitation of the soluble uranium will occur (ATSDR 2013). Insoluble uranium is not mobile.

As with soil, factors that control the mobility of uranium in water include ORP, pH, and sorbing characteristics of sediment, and suspended solids in water (Brunskill and Wilkinson 1987). The chemical form of uranium determines its solubility. Uranium behaves differently in oxidizing and reducing waters because of its two valence states (uranium reduced in the +4 valence state

[U(IV)] and oxidized in the 6+ valence state[U(VI)]). In the reduced state, uranium is insoluble and relatively immobile. In the oxidized state, uranium readily forms highly soluble complexes such as $UO_2\,(CO_3)_2^{2-}$ (McKelvey et al. 1955).

5.3.3 Radium

It has been experimentally demonstrated that radium can be adsorbed by soils and sediments (Benes and Strejc 1986; Landa and Reid 1982), and ferric hydroxide and quartz (Benes et al. 1984; Valentine et al. 1987). Consequently, it is usually not a mobile constituent in the environment. Radium K_d values for sand range from 18 to 1,742 mL/g in a pH range of 7.4 to 8.3 (Benes et al. 1984; Valentine et al. 1987). The magnitude of these adsorption constants indicates that partitioning to solid surfaces is a major removal mechanism of radium from water. Therefore, it is likely that radium in water does not migrate significantly from the area where it is released or generated (EPA 1985). Radium may be transported in the environment in association with particulate matter. Its concentration is usually controlled by adsorption/desorption mechanisms at solid-liquid interfaces and by the solubility of radium-containing minerals.

Some radium salts are soluble in water. Radium in water exists primarily as a divalent radium ion (Ra^{2+}) and has chemical properties that are like barium, calcium, and strontium. The solubility of radium salts in water generally increases with increased pH levels. The removal of Ra^{2+} by adsorption has been attributed to ion exchange reactions, electrostatic interactions with potential determining ions at mineral surfaces.

The adsorptive behavior of Ra^{2+} is like that of other divalent cationic metals in that it decreases with an increase in pH and is subject to competitive interactions with other ions in solution for adsorption sites. In the latter case, Ra^{2+} is more mobile in groundwater that has a high total dissolved solids content. Limited field data also support the generalization that radium is not very mobile in groundwater. It appears that the adsorption of Ra^{2+} by soil and rocks may not be a completely reversible reaction (Benes et al. 1984; Benes et al. 1985; Landa and Reid 1982). Hence, once adsorbed, radium may be partially resistant to removal, which would further reduce the potential for environmental release and human exposure.

As shown on **Table 5-1**, there is a wide range of predicted K_d values for radium (57 – 530,000 mL/g). The range is based on K_d values measured for sands and silts which describe the geology at the site. K_d values based on pH were not available for radium; however, it is expected that for soils of pH < 3, the K_d value for radium would decrease.

5.4 Contaminant Migration

This section discusses the conditions at the site that may affect contaminant transport, potential contaminant transport pathways, potential contaminant transport mechanisms, and transport properties in soil and groundwater. The chemical properties discussed above show that Th-232 is less mobile than U-238 and Ra-226, with Ra-226 the more mobile of the two. However, in the context of the site, all three radionuclides are expected to have low mobility and similar fate in the site media. For the purposes of discussing transport at the site, the three radionuclides are discussed together. Potential migration mechanisms for the contamination include surface water runoff, mobility in the soils, and discharge to the sewer system and sewer outfall sediments. The radionuclides decay to form radon and thoron, inert gases capable of being transported to

if sulfuric acid was used in processing the thorium, the radium as a sulfate is insoluble and not mobile aboveground air and infiltrating buildings above soils contaminated with Th-232, U-238, and Ra-226.

Based on the nature of the radionuclides and the similar extents of contamination, the three radionuclides are expected to behave similarly in the environment at the site.

5.4.1 Source Media

The primary source of radionuclides at the site was the processing of imported monazite sands for rare earth elements extraction. Monazite, a rare-earth and thorium phosphate material, is the primary source of the world's thorium, containing at least 6 percent to 8 percent thorium and to a lesser degree, uranium, of which monazite contains 0.1 to 0.3 percent. Monazite is very stable chemically, but it is susceptible to strong mineral acids such as sulfuric acid at high temperatures. In the acid treatment for rare earth metals extraction, finely ground monazite sand is digested at 155 to 230 degrees Celsius with highly concentrated sulfuric acid. This converts both the phosphate and the metal content of the monazite to water-soluble species. The rare-earth metals are extracted, leaving two byproducts: a process liquor consisting of thorium and uranium dissolved in the sulfuric acid and process tailings containing thorium and uranium.

The kiln-vat building where the processing took place is located on Lot 44 where the Primo Auto Body car storage bay currently exists. The arches of the kilns are still visible. The storage yard to the south of the kiln-vat building was likely used for the loading and unloading of thorium-bearing material to and from the kiln-vat building. Monazite sands and waste tailings were likely stored here and in the larger former storage yards that previously made up Lot 33.

The process liquors, including thorium, were considered a waste product and disposed of in the combined sewer system. The AEC began buying the thorium from WACC in the form of a thorium oxalate sludge in 1954, approximately 30 years after WACC started operations.

5.4.2 Transport of Process Liquors – Disposal in Soils and Sewer

<u>Soils</u>

Following processing, the process liquors were likely disposed into drains that flow underneath the WACC buildings leading to the sewer system. Soil contamination under the WACC buildings is likely attributable to process liquor exfiltration via leaky drains and sewer pipes, and other surficial discharges within or adjacent to the kiln/vat building. The soils at the site are composed of silty sands, sands, and gravel. The sands, composed mostly of silica, have poor sorption characteristics. Additionally, the soil is expected to have low alkalinity and low organic content, therefore, lacking the capability to form soluble complexes. However, since the radionuclides would typically be present as insoluble particles in the soils, they would not be expected to migrate down through the soil matrix via water or rain infiltration. The radionuclides are readily adsorbed by earth materials, rendering them immobile in the environment.

However, the heated sulfuric acid used during the monazite sands processing at the site acted as a strong oxidizing agent, rendering the radionuclides into an oxidized state and thereby, mobilizing the radionuclides to migrate through the subsurface as the process liquors were continually discharged from the kiln/vat building to a potentially leaking drain or sewer. The process liquors would be expected to continue downward through the soil while the force of advection from the disposal continued to have an effect, diffusing into the porosity of the soils. The process liquors would dilute in the presence of water such a rainwater infiltration which would decrease the viscosity of the process liquors, and would have a net effect of increasing the velocity of the sulfuric acid downward through the soil. However, the water would also slightly increase the pH of the environment and would react with the radionuclides to form insoluble and immobile compounds. This would prevent the radionuclide contamination from extending deeper in the soils.

Since the monazite sands processing activities at the site ceased in 1954, the radionuclides would not be expected to leach to groundwater as the water table is approximately 60 feet bgs. However, if the radionuclides were transported to the groundwater table, it would only happen in the presence of the sulfuric acid which would lower the pH of the groundwater, potentially mobilizing the radionuclides in the groundwater until the process liquors were sufficiently diluted to return the groundwater pH to neutral, changing the speciation of the radionuclides. At neutral pH, the radionuclides would be expected to precipitate out of solution and adsorb to soils.

Sewers

The process liquors from the rare-earth materials extraction process were disposed in the sewers. The process liquors containing radionuclides dissolved in sulfuric acid flowed toward the west, downgradient in the sewer system. As the liquors were diluted with incoming waste water and humic material, the sulfuric acid was neutralized and the radionuclides formed mobile complexes with humic matter but also, with the neutral pH, precipitated out of solution. The mobile complexes with the humic matter continued down the sewer line, moving to the sewer system outfall. The insoluble and immobile radionuclides adsorbed to particulates and settled out of the sewer water, become part of the sewer sediments and sanitary sewer sludge in the pipeline and manholes. Additionally, the radionuclide complexes would diffuse into the pore structure of the sewer building materials.

Some adsorbed radionuclides traveled in particulate form to the CSS outfall during CSO events. At the outfall, the radionuclides would be transported through the water column by advection from the discharging wastewater and sorbed to the sediment at the creek bottom due to the high concentration of organic carbon.

5.4.3 Transport of Monazite Sands and Tailings – Stockpiling, handling, and filling

Monazite sands were unloaded from the rail spur and stockpiled in the former storage yards along with the process tailings. Handling of the sands and tailings likely spread them throughout the former storage yards and rail spur areas.

Filling/Spreading

The tailings from the rare-earth materials extraction process were thought to have been disposed of by filling/spreading at the site and potentially adjacent areas. The radionuclides in the tailings are insoluble and immobile and would not be expected to leach deeper into the soil matrix.

Surface Water Runoff

Surface water runoff from the storage areas and the former rail spur would have eroded monazite sand stockpiles or tailing stockpiles, carrying contaminants to downgradient locations or media via overland runoff water. Topography at the site slopes gently to the southwest. Surficial runoff likely transported the sands and tailings from localized areas in the storage yards to downgradient areas near the property including the former rail spur, the Moffat and Irving Avenue intersection, and 338-340 and 350 Moffat Avenue. The radionuclide contamination is expected to persist in the surface soils consisting of fill material as insoluble compounds due to the neutral pH of the soils. The high partitioning coefficients of the radionuclides and the immobile nature of the insoluble compounds would prevent the contaminants from leaching deeper into the soil column. This is evidenced by the presence of contamination only in the upper four feet of soils in those parts of the site.

Particulate Emissions

The storage yards were likely used to stockpile the monazite sands and the process tailings. These monazite sands contain at least 6 percent to 8 percent of thorium while the tailings could contain between 0.02 percent and 0.6 percent thorium (International Atomic Energy Agency [IAEA] 2003). The sands and tailings would be mobilized to the air by wind agitation and were then transported by the wind as fugitive airborne dust, traveling in particulate form. This process may have been significant as the former storage yards were open to the air with little to no vegetation visible in the aerial photographs. Additionally, there were no surrounding structures to prevent the wind from carrying the fugitive dust from the stockpiled areas. The particulates would be removed from the atmosphere by dry deposition due to the weight of the particles, settling on soils near the WACC property.

5.5 Conceptual Site Model

This section discussed the current understanding of site conditions, the contaminant release mechanisms, the fate and transport of the site contaminants, and receptors. These elements are illustrated in **Figure 5-1** and described below.

5.5.1 Physical Setting

The WACC property is at an elevation of approximately 70 feet above mean sea level (amsl), and the ground surface in the area generally slopes gently to the southwest. The eastern edge of the site abuts an elevated train line that runs parallel to Moffat Street. The ground surface rises sharply toward the train line. Most of the runoff on the property flows to the south and southwest toward Irving Avenue, Moffat Street, and the southern corner of the former rail spur area. Runoff collects in catch basins at the intersection of Irving Avenue and Cooper Street and is routed into the CSS on Irving Avenue. The sewer runs down Irving Avenue, making a turn on Halsey Street before joining larger sewers on Wyckoff Avenue.

Soils at the site are made up of two types of unconsolidated material: fill and Upper Glacial Aquifer deposits (till and outwash). The fill contains man-made materials intermixed with silt, sands and gravels and ranges in thick at the site from 0 to 15 feet bgs. In the absence of man-made debris, it is difficult to distinguish between the two layers of material. This is representative of regrading of native materials.

A significant portion of the upper fill layers observed in borings at the WACC property and in some borings to the south on Moffat Street was a black, gray, and/or white cinder or ash-like material. This material is likely the contaminated waste tailings and was found between 0-4 feet bgs near the WACC property and between 0-6 feet bgs along Moffat St.

Below the urban fill, the upper portion of the glacial deposits is made up of glacial till which is yellowish brown dense silty sand and gravel. Underlying the glacial till is glacial outwash, slightly more uniform and coarse in texture than the till and extending from the bottom of the till to the depth of exploration at the site.

The depth to groundwater at the site is about 60 feet bgs. The saturated thickness of the aquifer is estimated to be about 111-114 feet depending on the depth to water at each well.

5.5.2 Extent of contamination

Contamination is present in WACC building materials, soils, sewer materials, sewer sediments, outfall sediments, and groundwater.

Buildings Materials

Radionuclides contamination was found throughout the WACC property buildings, primarily embedded in the building structures that previously operated as the kiln/vat building where the monazite sand processing occurred and in the basement of the deli next door.

Soils

Under the WACC buildings, contamination extends down to a depth of 28 feet bgs under Lot 44, the former kiln/vat building, and down to 24 feet bgs under Lot 42 feet bgs, the former yard where the monazite sands were loaded into the kiln/vat building for processing.

There is widespread surficial contamination related to surficial runoff/erosion or filling of tailings or monazite sands. Surficial contamination was observed in the former rail spur area, at the intersection of Irving Avenue and Moffat Street, the northern portion of Moffat Street and the eastern portion of Irving Avenue, and in the northern portion of 338-348/350 Moffat Street. This contamination was likely caused by stockpiling the tailings or the monazite sands in the former storage yards without covers, allowing wind and surface runoff to transport the sands and tailings to lower topographic areas.

Sewers

Gamma counts 20 times background levels (primarily from Th-232 in solids within the structures) begin at the manhole south of the WACC buildings and continue in the sewer pipeline and manholes on Irving Avenue for approximately two blocks (750 feet). Contamination is within the pipes and the manholes with contamination found in sediments/sludge and construction materials in the sewer manhole vaults located near the WACC property.

Gamma counts drop to four times background at the intersection of Irving Avenue and Schaeffer Street and drop to background at the intersection of Irving Avenue and Eldert Street with sporadic occurrences (likely related to areas where sediment/sludge accumulated) of gamma levels above four times background continuing in the sewer along Halsey Street to Wyckoff Avenue. Th-232 contamination was found above its screening criterion in the sediments at the sewer outfall in Newtown Creek.

Groundwater

Th-232 was detected in one groundwater sample during Round 2. The Th-232 was only slightly above the screening criterion. However, soil contamination was not detected deeper than 26 feet bgs, and since the groundwater table at the site is at approximately 60 feet bgs, it is uncertain that the soil contamination at the site caused any groundwater contamination. Another groundwater sampling event was conducted in November 2016 to confirm the Round 2 result; the results are pending.

5.5.3 Contaminant Sources and Pathways

This section describes the movement of the primary contaminants from the manufacturing process to the site media, including the building structure, overburden soil, sewer sediment and building materials, and groundwater.

Sources of Radionuclide Contamination

The sources of radionuclide contamination are the monazite sands and the production process byproducts. The sands were transported by rail to the rail spur adjacent to the property and were stockpiled in the southern former storage yard. From here, they were moved to the yard adjacent to the former kiln vat building and entered processing through the archways of the kiln vat building that are still present. The monazite sand processing took place in the kiln/vat building.

The process liquors and tailings were byproducts of the production process and contain high concentrations of radionuclides which were a waste product. The former storage yards were likely used to stockpile these tailings; the tailings were also used to fill areas within the WACC property as well as adjacent areas on Moffat Street.

Pathways for Contaminant Release/Transport

Process liquor disposal in soils – The process liquors were disposed into drains leading to the combined sewer systems. The soil contamination is likely attributable to process liquor exfiltration via leaky drains and sewer pipes, and other surficial discharges within or adjacent to the kiln/vat building. Once the process liquor entered the soil matrix, it traveled down through the soil column. The radionuclides in sulfuric acid were mobile and were transported to an observed 26 feet bgs in the soils. The tendency is for radionuclides to form insoluble and immobile compounds, except in the presence of low pH. When the sulfuric acid containing the more soluble and mobile radionuclides became diluted in the subsurface, the radionuclides formed immobile and insoluble complexes adsorbing to soils.

Process liquor disposal in sewers – Upon entering the CSS, the process liquors were diluted with incoming sewer water from other sewer branches. The radionuclides fell out of solution and adsorbed to particulate matter, traveling with the sediment to the outfall in particulate form or accumulating within the sewers as sediments.

Stockpiling, handling, and filling – Monazite sands were unloaded from the rail spur and stockpiled in the former storage yards along with the process tailings. Handling of the sands and tailings likely spread them throughout the yard and rail spur areas. Surficial runoff likely transported the sands and tailings from localized areas in the storage yards to downgradient areas near the property including the former rail spur, the Moffat and Irving Avenue intersection, and 338-340 and 350 Moffat Avenue. Additionally, transport of radionuclide-laden dust and particulates from the uncovered stockpiles in the air likely contributed to the surficial soil contamination found in the adjacent properties.

Human and ecological receptors

Human receptors may be exposed to the principal radionuclides through direct contact with the following: contaminated buildings materials in the buildings at Lots 46, 44, and 42; with the radionuclides-contamination soils at the WACC site; and, through direct contact with contaminated sewer materials and sewer sediments.

Human receptors may also be exposed to the principal radionuclides by external radiation in areas where high exposure rates were detected above background concentrations caused by radiation emanating from contamination materials such as building materials, soils, and sewer materials and sediments. sidewalks should be considered as well even though they are above the contaminated soils

Since the principal radionuclides at the site decay to form radon and thoron, radioactive gases that travel through soils and building materials, human receptors can be exposed to the contaminants through the inhalation of radon and thoron in the air emanating from building materials, soils, and sewer materials and sediments.

Th-232 was detected in sediment at the Newtown Creek outfall. Ecological receptors, which are only present in Newtown Creek and not at the site, could be exposed to the radionuclides in the aquatic system through direct contact with the sediments at the Newtown Creek outfall.

The Human Health and Ecological Risk Assessments provide a full discussion of potential exposure pathways and potentially impacted receptors.

Section 6

Risk Assessment Summaries

As part of the RI/FS, a baseline HHRA and a focused SLERA were conducted to determine if any threat to public health, welfare, or the environment may exist resulting from the release or threatened release of contaminants at or from the WACC site.

6.1 Human Health Risk Assessment

The HHRA is developed to characterize potential human health risks associated with the site in the absence of any remedial action. The HHRA is conducted in accordance with current EPA guidance outlined in Risk Assessment Guidance for Superfund (RAGS), Parts A, D, E, and F and other EPA guidance pertinent to human health risk assessments (EPA 1986, 1989, 1991, 1992). Key components of the HHRA include data evaluation, exposure assessment, toxicity assessment, risk characterization, and evaluation of uncertainties. Results of the HHRA are summarized below.

6.1.1 Data Evaluation

The data evaluation included an assessment of data usability and suitability for risk assessment purposes and identification of chemicals of potential concern (COPCs) and radionuclides of potential concern (ROPCs). COPCs and ROPCs were identified based on criteria outlined in RAGS, primarily through comparison to risk-based screening levels. COPCs were identified for surface and subsurface soil and groundwater by comparison of maximum detected concentrations in site media to EPA regional screening levels for residential soil and tap water. Maximum detections of radionuclides in site media were compared to EPA preliminary remediation goals for residential soil and tap water to select ROPCs.

Twenty-six chemicals were identified as COPCs in soil and groundwater at the site. COPCs for soil include SVOCs, pesticides, a PCB, and metals. COPCs for groundwater include VOCs and metals. Seven radionuclides were identified as ROPCs in soil and two radionuclides were selected as ROPCs.

6.1.2 Exposure Assessment

The exposure assessment describes exposure scenarios in which people make contact with site-related COPCs and ROPCs and provides equations and parameters to quantify exposure. Results of the exposure assessment are integrated with chemical and radionuclide-specific toxicity information to characterize potential risks.

Exposure pathways for the site are defined based on possible source areas, release mechanisms, and current and future uses of the site. Receptors evaluated in the risk assessment are listed below.

- Current and future ~~commercial~~ indoor workers
- Current and future industrial workers

- Current and future trespassers
- Current and future public users of the WACC property and surrounding area
- Current and future nearby (off-property) residents and workers
- Current and future school children
- Future construction/utility workers
- Future on-property residents

Exposure routes evaluated for the above receptors include: suggest adding which receptor for each route

- External radiation from surface and subsurface soil, outdoor surfaces, and interior surfaces
- Direct contact with radionuclides in surface soil (i.e., ingestion, inhalation, and external radiation) construction and utility workers
- Direct contact with radionuclides in subsurface soil (i.e., ingestion, inhalation, and external radiation) construction and utility workers
- Direct contact with radionuclides in sewer sediment (i.e., ingestion, inhalation, and external radiation) construction and utility workers
- Inhalation of radon and thoron in indoor air all receptors
- Direct contact with chemicals in surface and subsurface soil (i.e., incidental ingestion, dermal contact, and inhalation of particulates)
- Direct contact with chemicals in groundwater used as drinking water (i.e., ingestion, dermal contact, and inhalation)
- Inhalation of vapors emanating from groundwater

Not all the above exposure pathways are evaluated for every receptor.

Exposure point concentrations (EPCs) for COPCs or ROPCs are used in the exposure assessment calculations to estimate potential chemical intake. The EPC is either the UCL on the mean or the maximum detected concentration for chemicals, with the UCL exceeding the maximum concentration.

Quantification of exposure includes evaluation of exposure parameters that describe the exposed population (e.g., contact rate, exposure frequency and duration, and body weight). Each exposure parameter in the equation has a range of values. Daily intakes are calculated based on the reasonable maximum exposure (RME) scenario (the highest exposure reasonably expected to occur at a site). The intent is to estimate a conservative exposure case that is still within the range of possible exposures. Central tendency (CT) assumptions are also developed when estimated risks under RME scenario exceed EPA's threshold risk range. CT scenarios reflect more typical exposures.

should indicate that radiation exposure quantification is somewhat different from chemical quantification

6.1.3 Toxicity Assessment

COPCs are quantitatively evaluated based on their noncancer and/or cancer potential. ROPCs are quantitatively evaluated based on their cancer potential. The reference dose and reference concentration are the toxicity values used to evaluate noncancer health hazards in humans. Inhalation unit risk and slope factor are the toxicity values used to evaluate cancer health effects in humans. These toxicity values are obtained from various sources following the hierarchy order specified by EPA. Cancer slope factors provided in the Residual Radiation (RESRAD) Onsite Version 7.2 model were used for radionuclides.

6.1.4 Risk Characterization

Risk characterization integrates the exposure and toxicity assessments into quantitative expressions of risks/health effects. To characterize potential noncancer health effects, comparisons are made between estimated intakes of substances and toxicity thresholds. Potential cancer effects are evaluated by calculating probabilities that an individual will develop cancer over a lifetime exposure based on projected intakes and chemical-specific dose-response information. In general, EPA recommends target risk values, (i.e., cancer risk of 10^{-6} [1 in 1 million] to 10^{-4} [1 in a 10,000] or a noncancer health hazard index [HI] of unity [1]), as threshold values for potential human health impacts. These target values aid in determining whether remedial action is necessary at the site.

Risks for all receptors are estimated using RME assumptions. Risks due to exposure to non-radioactive COPCs are also estimated using CT assumptions when the RME assumptions result in risk estimates above EPA's thresholds. Radiological risk to all receptors was assessed using RESRAD onsite model Version 7.2, a model developed and maintained by Argonne National Laboratory. Estimated risks are summarized below.

Current Receptors Chemical Risk

Due to the developed nature of the site, direct exposure to COPCs in soil is limited for current receptors. In addition, groundwater is not currently used for any purpose at or near the site; therefore, direct exposure to contaminants in groundwater was not evaluated for current receptors. However, exposure to VOCs in groundwater via vapor intrusion was qualitatively evaluated by comparing maximum concentrations of VOCs in groundwater to EPA Vapor Intrusion Screening Levels (VISLs) for groundwater. This analysis found that VOCs are present at concentrations in groundwater exceeding VISLs. However, this finding is based on default assumptions that may overestimate the potential for exposure from vapor intrusion.

Current Receptors Radiation Risk

Complete exposure pathways for current receptors to ROPCs include external radiation from soil, external radiation from outdoor and indoor surfaces, and inhalation of radon and thoron in indoor air. Cancer risks were estimated in RESRAD for non-radon-related cancer risks and radon-related cancer risks. Non-radon-related cancer risk for commercial indoor workers and industrial workers exceeds EPA's target cancer risk range, primarily due to external exposure to Th-232 (over 90 percent), with the remaining fraction associated with Ra-226 and K-40. Inhalation and soil ingestion pathways make negligible contribution to risk. Cancer risk due to exposure to radon was estimated to be significantly higher than exposure to external gamma radiation. EPA installed shielding in most of the work areas and radon mitigation systems in some areas on the WACC property in 2013. Shielding was shown to be effective in reducing exposure when only concrete was used, and the denser steel and lead shielding used provided even greater protection.

High risk estimates (above 1×10^{-4}) for current workers suggest some potential for the general public to experience exposure above regulatory thresholds. The general public would encompass people visiting sidewalks along streets at and near the site where radionuclides have been transported as well as people frequenting businesses at and near the site. Possible exposure for the general public is mitigated by the installation of steel and lead shielding in some sidewalk areas where soil contamination is greatest.

People living and working in the neighborhood, particularly those receptors that spend significant time along streets where radionuclides were transported in and, perhaps, around sewer lines may be exposed to contamination present in the area. Exposures are likely to be less than exposures for indoor workers at the site for three reasons. First, little near-surface contamination is present, and the vadose zone and sidewalks and other hardscape will provide shielding. Second, radiological contaminants in the sewer sediments are more diffuse and well shielded by the piping and overlying street pavement. Third, people will spend less time than indoor or industrial workers on the streets above site-related contamination.

Future Receptors Chemical Risk

Future on-property residents and industrial workers were quantitatively evaluated for exposure to COPCs in surface soil. Cancer risk exceeds EPA's target threshold for future residents and is at the upper end of EPA's target range for industrial workers. The primary COPC cancer risk drivers are Aroclor 1260 and benzo(a) pyrene in surface soil. Hot spots for these COPCs are present on the WACC property. Noncancer health hazards associated with exposure to surface soil for future residents exceed the target threshold due to exposure to selenium which affects the nervous system, blood, and skin.

Future on-property residents and commercial indoor workers were also quantitatively evaluated for exposed to COPCs in groundwater used as drinking water. Groundwater is not currently used for drinking water at the site. Future potable use of groundwater is unlikely because a municipal water supply is readily available and serves the site and vicinity. Cancer risk exceeds EPA's target threshold for future residents due to exposure to hexavalent chromium assumed to be present in groundwater based on total chromium measurements. Cancer risk for future commercial indoor workers is at the upper end of EPA's target range. Noncancer health hazards for both future residents and commercial indoor workers exceed EPA's target threshold due to future hypothetical use of groundwater as drinking water. Health hazards are primarily due to exposure to PCE and TCE; PCE affects the liver and TCE affects the kidney.

Cancer risk for future construction/utility workers exposed to COPCs in surface/subsurface soil is within EPA's target range of 1×10^{-6} to 1×10^{-4}. Noncancer health hazard associated with exposure to surface/subsurface soil for future construction/utility workers is below the target threshold, suggesting that noncancer health hazards are not expected.

Exposure to VOCs in groundwater via vapor intrusion was qualitatively evaluated by comparing maximum concentrations of VOCs in groundwater to EPA VISLs for groundwater. This analysis found that VOCs are present at concentrations in groundwater exceeding VISLs. However, this finding is based on default assumptions that may overestimate the potential for exposure from vapor intrusion.

more related to Th-232 decay products than Th-232. clarify statement

Future Receptors Radionuclide Risk

Total cancer risk for future on-property residents, excluding radon, ranged from 1.6 to 2.7×10^{-3} between year 1 and year 30 and was relatively constant thereafter. Cancer risk was dominated by external exposure, which accounts for 80 to 90 percent of estimated risk. Th-232 was responsible for most (>90 percent) of risk due to external exposure. The total cancer risk estimate, including radon, is 1×10^{-3}. Rn-220, a daughter of Th-232, is also called thoron to distinguish it from Rn-222 in the U-238 decay chain. Rn-220 is seldom of concern for health risk because of its short half-life (56 seconds). The term "radon" in this assessment includes both Rn isotopes, but Rn-222, a daughter of Ra-226, is typically responsible for all risks associated with radon emanation.

Risks for both indoor and industrial workers are anticipated to be much the same as risks for current workers. Any future commercial or industrial construction is likely to have a substantial on-slab foundation, which should provide much the same shielding as the shielding previously put in place. Total cancer risk for future workers, excluding radon, ranged to 2×10^{-4} and to 2×10^{-3}, including radon.

inhalation & ingestion must be considered

Future development of the site would require construction workers to be on site without benefit of shielding for up 100 work days. Although this exposure is short-term, taking place within a single calendar year, ground shine and contact with contaminated soils would be intimate. Cancer risk for construction workers would be about 3×10^{-5}. For utility workers exposed to sewer sediment, cancer risk would be about 6×10^{-5}.

Future risks for the general public and for offsite receptors are assumed to be similar to current risks for these receptors. No changes to the surrounding neighborhood were contemplated in the conceptual site model for the site, and without remediation, half-lives of radionuclides are high enough to maintain existing exposure levels for an extended period. High risk estimates (above 1×10^{-4}) for workers suggest some potential for the general public to experience exposure above regulatory thresholds.

6.1.5 Summary

The HHRA presents risk estimates for various scenarios whereby people could be exposed to COPCs found in soil and groundwater and for ROPCs found in soil, outdoor and indoor surfaces, air, and sewer sediment.

In general, EPA recommends a target HI value of unity (1) and a target cancer risk range of 1×10^{-6} to 1×10^{-4} as threshold values for human health impacts. Both chemical- and radiation-related risks are higher relative to protective threshold criteria. Chemical risks for future receptors exceed the top of EPA's risk range or approach that level of risk. Chemical risk drivers in soil include PAHs and Aroclor 1260. Radiation risks frequently exceed the top of the risk range, surpass 10^{-3} in several instances, and the highest risks exceed 10^{-2}.

High cancer risk estimates are not unusual for radiological contaminants in an environmental setting. Background levels of radiation exposure in residential settings can be associated with risks approaching and often exceeding EPA's risk range. Risk estimates can also be interpreted in terms of annual radiation dose, which is a common means of assessing health risk in the nuclear physics community. The highest annual dose estimates, which approach or exceed 100 millirems (mrem), also exceed typical risk screening levels of 12 and 25 mrem/year for residential and occupational exposure. indicate that this is above nominal background exposures

see comment above

The highest site-related risks are due to external exposure to gamma radiation and to inhalation of radon gas that collects indoors. Th-232 is responsible for over 90 percent of external radiation exposure, and Ra-226, as the parent of Rn-222, is responsible for a similar percentage of risk due to inhalation of radon. Th-232 and Ra-226 are likely to be primary risk drivers for risk management decisions.

Groundwater is not currently used as drinking water, and it is unlikely to be used as such in the foreseeable future; however, drinking water scenarios were evaluated for future residents and future commercial indoor workers. Chemical risk drivers in groundwater at the site include PCE, TCE, and hexavalent chromium. PCE and TCE contaminant plumes likely originate from upgradient sources and are unlikely to be site-related. The risk due to exposure to hexavalent chromium in groundwater is most likely overestimated because the HHRA assumes that hexavalent chromium is present as a fraction of the total chromium measured concentration. K-40 eventually could present a risk via consumption of contaminated groundwater but not for several centuries. Moreover, this nuclide is unlikely to be enhanced by previous site operations and probably represents naturally occurring K-40 in materials brought to and used at the WACC property.

K-40 is biologically regulated so most environmental assessments ignore its contribution to risk

6.2 Screening Level Ecological Risk Assessment

The site is in an industrial area with no environmentally sensitive areas (e.g., wetlands) and only limited habitat for most types of ecological receptors; thus, adverse exposures for ecological receptors at the site are unlikely. Due to the extremely limited habitat, a full SLERA was not conducted; instead a focused screening evaluation was conducted. The purpose of this focused SLERA is to describe the likelihood, nature, and extent of adverse effects in ecological receptors exposed to site-related radionuclides as a result of releases to the environment from past processing activities at the site. Because CSO discharges at the site may contain thorium waste from monazite sand processing, this evaluation focused on risks to ecological receptors exposed to the site-related CSO discharges in Newtown Creek (approximately 1.9 miles to the northwest). Newtown Creek is a tidal arm of the New York-New Jersey Harbor Estuary.

Receptors that could be exposed to radionuclides in the aquatic ecosystem include aquatic and riparian vegetation, aquatic animals, riparian animals, and other animals that use aquatic resources. It was determined that the generic riparian animal was the limiting organism for the sediment exposure pathway. External dose exposure pathways for riparian animals include: exposure to radionuclides in sediment and exposure to radionuclides in water. Internal dose exposure pathways include: exposure to radionuclides via ingestion of contaminated vegetation, including water content with dissolved nutrients and minerals, and exposure to radionuclides biomagnified through the food web.

The data used in this analysis consists of results from sediment samples collected from 5 locations at each of the 2 CSOs in Newtown Creek and from 10 locations in Coney Island Creek, a

Superfund site?

reference location. These sediment data were used to evaluate potential exposure to aquatic biota by comparing the results to screening criteria determined using the RESRAD-BIOTA model.

The RESRAD-BIOTA model was used to estimate sediment biota concentration guides (BCGs) for riparian receptors. Each radionuclide-specific BCG represents the limiting radionuclide concentration in an environmental medium which would not result in recommended dose standards for biota to be exceeded. BCGs define doses below which risks to populations are assumed not to occur. This definition simplifies those steps conducted in a typical ecological risk assessment that involve assessing the relationship between stressor levels and ecological effect, characterizing, estimating, and assessing risks. Comparison of site concentrations to BCGs essentially characterizes risks for the population of concern.

Maximum and mean radionuclide concentrations measured in sediment were compared to BCGs for riparian animals in the aquatic ecosystem. The results of the screening evaluation verify that radionuclide concentrations in sediment in the East Branch of Newtown Creek are significantly less than BCGs and that dose to receptors is below biota dose limits. The bulk of measured radioactivity in sediment is likely due to natural background of radionuclides except for the thorium isotopes (i.e., Th-228, Th-230, and Th-232) and their progeny. Further supporting conclusions of low or insignificant risk to ecological receptors are observations that the site and nearby areas provide only limited ecological habitat.

Section 7

Conclusions and Recommendations

The significant findings of the RI are summarized below.

7.1 Conclusions

The RI investigation confirmed findings of the previous investigations and provided data adequate to complete the risk assessments and feasibility study. The major conclusions are summarized below:

- Radionuclide contamination remains in the building structures at the WACC property, primarily in the buildings that previously operated as the kiln/vat in which monazite sand processing took place and the storage yard where sands were loaded into the kiln-vat (Lots 42 and 44), in the basement of the deli (Lot 46), and to a lesser extent, in the warehouse on Lot 33 that was constructed above a former yard area.

- ACM, LBP, and other suspect hazardous materials were found in the WACC building structures.

- Under the WACC buildings, radiological contamination extends down to a depth of 28 feet bgs under Lot 44, the former kiln/vat building, and down to 24 feet bgs under Lot 42, the former yard where the monazite sands were loaded into the kiln/vat building for processing.

- There is widespread surficial radiological contamination related to storage or filling of tailings or monazite sands and/or surface runoff/erosion from those areas. Surficial contamination was observed in the former rail spur area, at the intersection of Irving Avenue and Moffat Street, the northern portion of Moffat Street and the eastern portion of Irving Avenue, and in the southeastern corner of Lot31/northern part of 350 Moffat (area adjacent to the Moffat/Irving intersection).

- PAH concentrations exceeding the screening criteria were found throughout the shallow soils at the WACC property. PAHs found as deep as 7 feet bgs may be related to former USTs or use of the area to store demolished cars. Similar concentrations were also found at the nearby property, 308 Cooper Street. PCBs exceeded the screening criteria by at least an order of magnitude in three locations. PCBs in the shallow soils can also be related to USTs or a sump below the building in Lot 33. Arsenic and iron concentrations exceeding the screening criteria were found in all samples at all depths and within the range of background levels, indicating the metals are likely associated with urban fill.

- Radionuclide contamination within the CSS is present near the WACC property in sediments/sludge and materials comprising the sewer pipes and manholes.

- Radionuclide contamination is significantly elevated in the manholes on Irving Avenue adjacent to the WACC buildings where process liquors containing high concentrations of radionuclides were likely discharged. The elevated gamma levels (>20 times background) continue in the sewer line and manholes on Irving Avenue for approximately two blocks to Decatur Street.

- Gamma levels generally drop to four times background at the intersection of Irving Avenue and Schaeffer Street and drop to background at the intersection of Irving Avenue and Eldert Street, with sporadic occurrences of gamma levels above four times background continuing in the sewer along Halsey Street to Wyckoff Avenue.

- Radionuclide concentrations in sediment at the Newtown Creek outfall are above screening criteria but limited to the area immediately adjacent to the outfall discharge. However, the ecological risk assessment verified that radionuclide concentrations in sediment do not pose unacceptable risk to ecological receptors.

- Chlorinated VOCs exceeded screening criteria in the groundwater at each of the five monitoring wells. However, chlorinated VOCs were not detected in the soil samples collected as part of the RI and previous investigations. Additionally, the Phase I report did not indicate the use of materials currently or in the past that would be associated with chlorinated VOCs. Therefore, it is likely that this contamination may be from an upgradient source.

- Exposure rate surveys confirmed the results from the previous exposure rate surveys conducted within the WACC buildings, on sidewalks, and on the streets near the WACC property are above background levels.

- Short-term radon levels collected in the day-care and school and long-term radon and thoron levels collected in the school were either below or equal to the screening criteria. Soil samples collected from the school area only slightly exceeded the screening criteria. However, the gamma exposure rates collected from within the school and daycare were all within or below the background observed for the neighborhood. These investigations showing data just slightly above RI screening criteria are not indicative of contamination due to the WACC processes.

Data gaps

- Delineation of radionuclide contamination in soils was not achieved in areas adjacent to the cabinet maker to the north of the WACC property suggesting potential concentrations above screening criteria may exist below the building.

- The sewer pipeline on Irving Avenue showed potential for exfiltration in several areas as indicated by the fiberscope investigation. Contamination was not observed in soil samples collected adjacent to the pipeline; however, samples were not collected from the bedding material below the sewer. This bedding material has the potential to be contaminated.

- Radionuclide contamination in the groundwater was limited to one groundwater sample result slightly exceeded screening criteria for Th-232. In order to better understand the nature of this detection, confirmation samples were collected in November 2016. The results are pending; the data will be incorporated into the RI when finalized.

7.2 Recommendations

- The data collected during the RI are considered to be sufficient to support development of remedial alternatives in the FS and preparation of a ROD.
- Data gaps can be addressed during the remedial design or remedial action.